LAMAR UNIVERSITY-BEAUMONT
0 00 01 1138516 7

Missouri. Division of Geological Survey---
Reports.

NON-CIRCULATING MATERIAL

NON-CIRCULATING MATERIAL

NON-CIRCULATING MATERIAL

DISCARDED

THE SAND AND GRAVEL RESOURCES OF MISSOURI

BY C. L. DAKE

1918

↑ 767989

VOL. XV, SECOND SERIES

Missouri. Geological Survey. /1
/Reports, 2d. Series/

QE
131
A13
Vol. 15

MISSOURI BUREAU OF GEOLOGY AND MINES
ROLLA, MISSOURI
H. A. BUEHLER, *Director and State Geologist*

SPINDLETOP ENGINEERING LIBRARY
LAMAR STATE COLLEGE OF TECHNOLOGY

BOARD OF MANAGERS.

His Excellency, Frederick D. Gardner, Governor of Missouri, ex officio President of the Board . . Jefferson City
Elias S. Gatch, Vice President . . . . . St. Louis
Major Clark Craycroft, Secretary . . . . . Joplin
Philip N. Moore . . . . . St. Louis
Edward M. Shepard, Sc. D . . . . . Springfield

SPINDLETOP ENGINEERING LIBRARY
LAMAR STATE COLLEGE OF TECHNOLOGY

TABLE OF CONTENTS.

Page

BOARD OF MANAGERS II
TABLE OF CONTENTS III
LIST OF ILLUSTRATIONS X
LETTER OF TRANSMITTAL XIII
INTRODUCTION XIV
Inception of the investigation XIV
Field work XIV
Laboratory studies XV
ACKNOWLEDGMENTS XVI

CHAPTER I.

NATURE, ORIGIN AND PROPERTIES OF SAND 1
Definition of sand 1
Origin of sand 1
Mechanical weathering 2
Chemical weathering 3
Classification of sand 5
Classification by origin 5
Classification by chemical content 5
Classification by mineralogical content 6
Classification by geographic distribution 7
Classification by stratigraphic distribution 7
Classification by sizes 7
Classification by uses 8
Properties of sand 8
Color 8
Cleanness 9
Size of grain 11
Screen tests 11
Uniformity coefficient 14
Effective size 15
Form of grain 16
Soundness of grain 18
Specific gravity 18
Voids 21
Weight of sand 27
Chemical composition 29
Refractoriness 30

CHAPTER II.

METHODS OF PRODUCTION AND MARKET CONDITIONS 31
Methods of loading sand 31
Loading by hand into wagons 31
Loading by hand into barges 32
Loading by hand into cars 33
Loading by hand with sand dippers 33
Loading with scraper and trap 33
Loading with steam shovel 34
Loading with clam shell dredge 34
Loading with cable drag-line 34
Loading with belt-bucket dredges 35
Loading with centrifugal pumps 35
Unloading from the barges 37
Unloading by clam shell 37
Unloading by box hoist 38
Unloading by car and track 38

Page

Unloading by belt elevator ... 38
Unloading by hand ... 38
Length of sand dredging season ... 39
Sand quarrying ... 39
Preparation of sand for the market ... 40
Crushing sand ... 40
Washing sand ... 40
Screening sand ... 42
Drying sand ... 43
Storage of sand ... 44
Selection of grades of sand ... 44
Conditions of the sand trade ... 45
Statistics of production ... 45
Markets ... 46
Competition from points outside the state ... 48
The glass sand market ... 49

CHAPTER III.

THE USES OF SAND AND GRAVEL ... 51
Building sand and gravel ... 51
Sand for mortar ... 51
Mortar for plastering ... 51
Cleanness ... 51
Size of grain ... 52
Sharpness ... 53
Color ... 53
Mortar for brick laying ... 53
Mortar for stone masonry ... 54
Sand and gravel for concrete aggregate ... 54
Properties demanded in good concrete aggregate ... 54
Cleanness in concrete aggregate ... 55
Size of grain in concrete aggregate ... 57
Voids in concrete aggregate ... 58
Shape of grain in concrete aggregate ... 60
Smoothness of grain in concrete aggregate ... 60
Strength of pebbles in concrete aggregate ... 61
Uses to which concrete is put ... 62
Roofing gravel ... 63
Sand for the manufacture of sand lime brick ... 64
Paving sand ... 64
Sand and gravel for pavement foundations ... 65
Sand for the cushion layer ... 65
Sand for asphalt pavements ... 66
Gravel for roads ... 69
Gravel for railroad ballast ... 72
Foundry sands ... 73
Cohesiveness ... 74
Refractoriness ... 74
Texture ... 75
Porosity and permeability ... 75
Durability ... 75
Engine sand ... 77
Filter sand and gravel ... 78
Glass sand ... 80
Grinding and polishing sand ... 84
Stone sawer's sand ... 84
Sand for sand blast work ... 85
Fire and furnace sand ... 85
Bedding sand ... 86
Minor uses for sand ... 86

CHAPTER IV.

THE DISTRIBUTION OF SAND AND GRAVEL BY GEOLOGICAL FORMATIONS AND DISTRICTS ... 87
General statement ... 87
PreCambrian ... 89
Lamotte ... 89

Page

Bonneterre ... 91
Davis ... 91
Derby ... 91
Doe Run ... 91
Potosi ... 91
Eminence ... 91
Proctor ... 92
Gunter ... 92
Gasconade ... 93
Roubidoux ... 93
Phelps County ... 93
Distribution ... 94
Thickness ... 94
General description ... 94
Miller County ... 96
Distribution ... 96
Thickness ... 96
Bolin Creek member ... 96
Morgan County ... 97
Maries County ... 97
Osage County ... 97
Cole County ... 98
Ste. Genevieve County ... 98
Ozark and Douglas Counties ... 98
Wright County ... 99
Laclede County ... 99
Pulaski County ... 99
Crawford County ... 100
Cape Girardeau County and Perry County ... 100
Jefferson County ... 100
Jefferson City ... 100
Cotter ... 101
Powell ... 101
Everton ... 101
Areal extent ... 101
Stratigraphic relations ... 103
Thickness ... 103
Structure of belt ... 103
Physiography of the belt ... 104
Lithologic character ... 104
Favorable localities ... 105
Use ... 105
St. Peter ... 105
Introductory ... 105
Areal extent ... 106
Stratigraphic relations of the St. Peter ... 108
Relations of the St. Peter to the Joachim ... 108
Relations of the St. Peter to Jefferson City ... 109
Relations of the St. Peter to Everton ... 111
Thickness of the St. Peter ... 112
Structure of the St. Peter belt ... 115
Folding ... 115
Faulting ... 116
Bedding ... 117
Cross bedding ... 118
Ripple marks ... 118
Physiography of the St. Peter belt ... 118
Lithologic character of the St. Peter ... 121
Composition of the sandstone ... 121
Size and uniformity of grain ... 126
Degree of rounding ... 127
Color ... 128
Cementation ... 130
Detailed county descriptions ... 131
Cape Girardeau County ... 131
Distribution ... 131
Outcrops ... 131
General nature of the formation ... 131

Page

Thickness ... 132
Favorable localities ... 132
Bollinger County ... 134
Perry County ... 134
Distribution ... 134
Outcrops ... 134
General nature of the formation ... 135
Thickness ... 135
Favorable localities ... 136
Ste. Genevieve County ... 138
Distribution ... 138
Outcrops ... 138
Nature of the formation ... 139
Thickness ... 139
Presence of the Everton ... 139
Favorable localities ... 139
Jefferson County ... 141
Distribution ... 141
Outcrops ... 141
General nature of the formation ... 141
Thickness ... 142
Presence of the Everton ... 143
Plants in operation ... 143
Pittsburgh Plate Glass Company ... 143
Enterprise Sand and Mining Company ... 147
Silica White Sand Company ... 148
Favorable localities ... 150
St. Louis County ... 152
Distribution ... 152
Outcrops ... 152
Nature of the formation ... 152
Thickness ... 153
Plants operating in the county ... 153
Pacific Glass Sand Company ... 153
Tavern Rock Sand Company ... 155
Favorable localities ... 156
Franklin County ... 156
Distribution ... 156
Outcrops ... 156
Nature of the formation ... 157
Thickness ... 157
Plants operating in Franklin County ... 157
Grays Summit White Sand Company ... 157
Tavern Rock Sand Company ... 159
J. W. Glaser ... 160
Favorable localities ... 160
St. Charles County ... 161
Distribution ... 161
Outcrops ... 161
Character of the formation ... 161
Thickness ... 161
Plants operating in the county ... 161
Tavern Rock Sand Company ... 161
Favorable localities ... 163
Warren County ... 163
Distribution ... 163
Outcrops ... 164
Nature of the formation ... 164
Thickness ... 164
Favorable locations ... 164
Montgomery County ... 165
Distribution ... 165
Outcrops ... 166
Character of the formation ... 166
Thickness ... 166
Favorable localities ... 166
Lincoln County ... 167
Distribution ... 167

Page

Outcrops ... 167
Nature of the formation ... 167
Thickness ... 168
Favorable localities ... 168
Sandstone of doubtful age, lithologically resembling the St. Peter ... 170
Joachim ... 171
Plattin ... 171
Decorah ... 171
Kimmswick ... 171
Fernvale ... 171
Thebes ... 172
Cape Girardeau ... 172
Noix ... 172
Bainbridge ... 172
Baily (Including Clear Creek?) ... 173
Little Saline ... 174
Grand Tower ... 174
Beauvais ... 174
St. Lorenz ... 175
Chattanooga ... 175
Other Devonian sandstones ... 175
Grassy Creek ... 176
Louisiana ... 176
Hannibal (Including Vermicular Sandstone) ... 176
Phelps ... 177
Chouteau (Including Northview) ... 177
Fern Glen ... 177
Burlington-Keokuk ... 178
Warsaw ... 178
Salem ... 178
St. Louis ... 178
Ste. Genevieve ... 178
Aux Vases ... 178
Renault ... 180
Pennsylvanian System ... 180
Pennsylvanian sandstone of the Ozarks ... 180
Pennsylvanian sandstone of northern Missouri ... 181
Asphaltic sandstones of the Pennsylvanian ... 181
General Statement ... 181
Location ... 182
Geology ... 182
Thickness ... 183
Accessibility ... 183
Amount of bitumen ... 184
Nature of the bitumen ... 185
Physical character of the sand ... 185
The Higginsville deposit ... 186
The Sheldon deposit ... 188
Value of the deposits ... 189
Tertiary ... 189
Ozark Tertiary ... 189
Commerce sandstone ... 191
Crowley's Ridge sands and gravels ... 192
Scott County ... 193
Ellis pits ... 193
Benton pit ... 199
Glassstetler pit ... 200
Stoddard County ... 200
Williams pit ... 200
Dexter pits ... 201
Dunklin County ... 201
Wetherholt pit ... 202
Dalton pit ... 202
Value of Crowley's Ridge gravels ... 202
Pleistocene sands and gravels ... 203
Glacio-fluvial deposits ... 203
Nodaway County ... 203
DeArmand pit ... 204

Page

Stark pit ... 205
Thornhill pit ... 205
Mozingo pit ... 205
Heitmann pit ... 205
Hasty pit ... 206
Thompson pit ... 206
Other occurrences of glacial-fluvial sands and gravels ... 207
Till gravels ... 208
South St. Louis moulding sands ... 208
John W. Allen and Son ... 208
Loess moulding sands ... 210
Recent sands and gravels ... 211
Residual deposits ... 211
River and creek sands and gravels ... 211
Mississippi River ... 211
Morrison Ice and Fuel Company ... 213
Universal Sand Company ... 213
H. B. Straight ... 214
Meramec Portland Cement and Materials Company ... 215
Union Sand and Materials Company ... 215
St. Louis plant ... 215
Hannibal plant ... 216
Canton Fuel Company ... 217
Louisiana Sand and Gravel Company ... 218
Missouri River ... 218
Pundeman, Theo ... 219
Jefferson City Sand and Gravel Company ... 220
Missouri River Sand and Gravel Company ... 220
Donnivant, Charles ... 221
Glasgow Sand Company ... 221
Lexington Triumph Press Brick Company ... 221
Stewart Peck Sand Company ... 222
Pioneer Sand Company ... 223
Buchanan Sand Company ... 224
Stream sands and gravels from the Ozarks ... 225
Meramec River ... 226
Continental Portland Cement Company ... 226
Union Sand and Materials Company ... 227
Meramec Portland Cement and Materials Company ... 228
Universal Sand Company ... 229
Moselle and other Meramec sands ... 230
Black River ... 231
Randels, J. H ... 231
Turner, H ... 232
Murphy, W. J ... 232
Missouri Pacific Railway ... 232
Joachim Creek ... 233
Harrison Brothers ... 233
Osage River and tributaries ... 233
Osage River Gravel Company ... 233
Chicago, Rock Island and Pacific Railway Company ... 234
Henley bar ... 234
Argyle bar ... 234
Little Piney Creek ... 234
Freeman, J. H ... 235
Pillman Brothers ... 235
Gasconade River ... 236
Other producers from minor Ozark streams ... 236
Menefee, Geo. T ... 236
Strange, C. W ... 236
Dunlap, John ... 237
Love Branch of the Little Dry Fork, Rolla ... 238
Streams of the glaciated area other than the Pennsylvanian ... 238
Salt River ... 238
G. W. Camery ... 238
Streams of the glaciated Pennsylvania area ... 239
Nodaway River ... 239
Bodle, Wm ... 239

Page

Carpenter, Fred 240
Roach, A 241
Cole and Jester 241
Mattox and Younger 241
Streams of the unglaciated Pennsylvanian area 241
Streams of the unglaciated Mississippian area 241
Elk River 241
Carmichael Gravel Company 242
Streams of the southeast lowland 242
Dexter Creek 243
Norman, F. M 243
List of sand and gravel plants reporting production 243

ILLUSTRATIONS.

Plate		Page
Ia	Gravel pit of Pacific Cement Gravel Company, near Pacific. Shows two typical loading traps	32
Ib	Osage River Gravel Company, Osage City. Bucket dredge operating on Osage River	32
IIa	Sand Quarry of Enterprise Sand and Mining Company, Herculaneum. Shows steam shovel loading quarry cars	34
IIb	G. W. Camery's plant on Salt River, near Hannibal. Shows cable drag line in operation	34
III	G. W. Camery's plant on Salt River, near Hannibal. Shows cable drag line in operation	35
IVa	Osage River Gravel Company, Osage City. Detail of dredge buckets	36
IVb	Harrison Brother's dredge, Joachim Creek, near Silica	36
Va	Canton Fuel Company's plant, at Canton, on the Mississippi. Shows pontoon pipe line from dredge to shore	37
Vb	Meramec Portland Cement and Materials Company's plant, at Sherman, on Meramec River. Shows water and gravel discharging from fifteen-inch centrifugal pump onto barge	37
VIa	Clam shell, Missouri River Sand and Gravel Company, at Boonville	38
VIb	Clam shell in operation. Union Sand and Materials Company, St. Louis.	38
VIIa	Plant of Pioneer Sand Company, St. Joseph. Shows clam shell handled by mast and swinging crane	39
VIIb	Plant of Union Sand and Materials Company, St. Louis. Shows track and traveling clam shell	39
VIIIa	Plant of Stewart Peck Company, Kansas City. Clam shell handled by traveling crane	40
VIIIb	Plant of Continental Portland Cement Company, Valley Park. Shows sand conveyed from clam shell to screening tower on endless belt conveyor	40
IXa	Box hoist, Osage River Gravel Company, Osage City	41
IXb	Plant of the Buchanan Sand Company, St. Joseph. Car and track for unloading sand	41
Xa	Open pit quarry in St. Peter sandstone. Silica White Sand Company, Silica	42
Xb	Quarrying St. Peter sandstone in tunnels, by mining methods. Pittsburgh Plate Glass Company, Crystal City	42
XIa	Screening and washing tower, plant of Meramec Portland Cement and Materials Company, at Sherman, on Meramec River	43
XIb	H. B. Straight's Filter Sand Plant, Crystal City. Washes and screens Mississippi River sand	43
XIIa	Plant of J. H. Freeman, Newburg. Furnace for drying engine sand	44
XIIb	Thin bedded Everton sandstone along roadside, N. E. ¼ sec. 26, Twp. 37 N., R. 8E., north of River aux Vases, Ste. Genevieve County	44
XIIIa	Contact of St. Peter sandstone and Joachim dolomite at Pacific. Note how cross bedding gives a deceptive appearance of discordance	109
XIIIb	The St. Peter-Joachim escarpment between Crystal City and Silica	109
XIV	Map of a portion of Cape Girardeau County, showing distribution of St. Peter sandstone	131
XVa	Veining in the St. Peter sandstone near the large fault west of Lithium, Perry County	132
XVb	Veining in the St. Peter sandstone near the large fault just north of Menfro, Perry County	132
XVIa	Cliff of St. Peter sandstone, just east of Dutchtown, Cape Girardeau County	133
XVIb	General view of plant of Pittsburgh Plate Glass Company, Crystal City	133
XVII	Map of parts of Perry and Bollinger Counties showing distribution of St. Peter and Everton sandstone	134
XVIII	Map of part of Ste. Genevieve County showing distribution of St. Peter and Everton sandstone	138

Plate		Page
XIX	Map of part of Jefferson County showing distribution of St. Peter and Everton sandstone	141
XXa	Quarry of Pittsburgh Plate Glass Company, Crystal City. Shows cliff of St. Peter sandstone, capped with Joachim dolomite	145
XXb	Quarry of Pacific Glass Sand Company, Pacific. St. Peter sandstone, capped with Joachim dolomite	145
XXIa	Plant of Enterprise Sand and Mining Company, Herculaneum	147
XXIb	Quarry of Silica White Sand Company, Silica. St. Peter sandstone	147
XXII	Map of mine workings of Pittsburgh Plate Glass Company at Crystal City	148
XXIII	Map of portions of Jefferson, St. Louis and Franklin Counties, showing distribution of St. Peter sandstone	152
XXIVa	Quarry of Pacific Glass Sand Company, Pacific. Open pit work in St. Peter sandstone	154
XXIVb	Plant of Pacific Glass Sand Company, Pacific	154
XXVa	Tunnel of Pacific Glass Sand Company, Pacific. Shows St. Peter-Joachim contact	155
XXVb	Quarry of Tavern Rock Sand Company, Klondike. Aerial tram to remove stripping	155
XXVIa	Tavern Rock Sand Company, Pacific. Shows working face of St. Peter sandstone with loess overburden	156
XXVIb	Tavern Rock Sand Company, Pacific. Loess overburden, stripped hydraulically	156
XXVIIa	Plant of Grays Summit White Sand Company, Grays Summit	158
XXVIIb	Klondike Plant, Tavern Rock Sand Company. Shows plant below quarry, allowing gravity operation	158
XXVIIIa	Quarry of Grays Summit White Sand Company, Grays Summit. St. Peter sandstone	159
XXVIIIb	Pacific Quarry of Tavern Rock Sand Company. St. Peter sandstone	159
XXIXa	J. W. Glaser's Quarry, Pacific. St. Peter sandstone	160
XXIXb	Klondike Quarry, Tavern Rock Sand Company. St. Peter sandstone	160
XXX	Map of portions of St. Charles and Warren Counties, showing distribution of St. Peter sandstone	161
XXXI	Map of portions of Montgomery and Callaway Counties, showing distribution of St. Peter sandstone	166
XXXII	Map of portion of Lincoln County, showing distribution of St. Peter sandstone	168
XXXIIIa	Ballast pit in tripolitic chert, Wittenberg, Perry County. Curved strata show slump	174
XXXIIIb	Gravel pit of Pacific Cement Gravel Company, Pacific. So-called Lafayette red gravel	174
XXXIVa	Joe Ellis gravel pit, Commerce, Scott County. Tertiary red gravel (Lafayette) used for road metal	194
XXXIVb	Glassstetler gravel pit, Benton, Scott County. Tertiary red gravel, (Lafayette) used for road metal. Shows loess overburden	194
XXXVa	DeArmand pit, Maryville, Nodaway County. Stripping till overburden	204
XXXVb	Glacio-fluvial gravel at the DeArmand pit, Maryville, Nodaway County	204
XXXVIa	Cross-bedding in DeArmand's gravel pit. Maryville, Nodaway County	206
XXXVIb	Jake Thompson's gravel pit, Guilford, Nodaway County. Shows channel in gravel filled with clay	206
XXXVIIa	Jake Thompson's gravel pit, Guilford, Nodaway County. Shows cross-bedding in glacio-fluvial gravel	207
XXXVIIb	Detail of above cross-bedding	207
XXXVIIIa	J. W. Allen and Sons' moulding sand pit, Pennsylvania and Haven Sts., Carondelet, St. Louis	208
XXXVIIIb	J. W. Allen and Son's moulding sand pit, Reilly and Prim Sts., Carondelet, St. Louis	208
XXXIXa	Dredge pump of the Universal Sand Company, Crystal City	213
XXXIXb	Plant of Meramec Portland Cement and Materials Company, foot of Dock Street, St. Louis. Shows clam shell in operation	213
XLa	Plant of Meramec Portland Cement and Materials Company, foot of Dock Street, St. Louis. Shows belt conveyor and loading hopper	215
XLb	Plant of Union Sand and Materials Company, foot of Tyler Street, St. Louis. Unloading a barge	215
XLIa	Plant of Union Sand and Materials Company, Hannibal	216
XLIb	Plant of Canton Fuel Company, Canton. Discharge of water and sand at stock pile	216
XLIIa	Dredge pump in operation, Jefferson City Sand and Gravel Company	220
XLIIb	Crane in operation, Jefferson City Sand and Gravel Company	220

Plate		Page
XLIIIa	Dredge of Stewart Peck Sand Company, Kansas City	222
XLIIIb	Crane and stock pile, Stewart Peck Sand Company, Kansas City	222
XLIVa	Plant of Pioneer Sand Company, St. Joseph	223
XLIVb	Dredge boat of Universal Sand Company, Pacific	223
XLVa	Plant of Universal Sand Company, Pacific	229
XLVb	Plant of J. H. Randles, Poplar Bluff, on Black River	229
XLVIa	Gravel bar at Mill Spring, Wayne County, Black River	236
XLVIb	Gravel bar on Little Piney, between Newburg and Arlington, Phelps County	236
XLVII	Map of Missouri, showing location of the sand and gravel plants in the State	243
Fig. 1.	Plot showing derivation of uniformity coefficient	15
Fig. 2.	Sketch showing method of computing thickness of formations	113

LETTER OF TRANSMITTAL.

Missouri Bureau of Geology and Mines,
Rolla, Mo., July 17, 1918.

To the President, Governor Frederick D. Gardner, and the Members of the Board of Managers of the Bureau of Geology and Mines:

Gentlemen: I have the honor to transmit herewith a report on the Sand and Gravel Resources of Missouri by Mr. C. L. Dake.

Missouri contains an abundance of both sand and gravel deposits which, besides forming an immense industry in their production, supply the needs of many other industries of great importance. Their use covers the widest range to which these materials can be placed, even to the manufacture of the finest grade of plate glass. The constant demand for information concerning these deposits and their uses has resulted in the investigation upon which this report is based, and I trust it will satisfactorily meet the many needs it is intended to serve.

Respectfully submitted,
H. A. Buehler,
Director and State Geologist.

INTRODUCTION.

Inception of the Investigation.—Field work on the mapping of the St. Peter sandstone was begun in 1907 by Mr. O. U. Stromme, of this Bureau, with a view to getting out a report on the glass sand industry of Missouri. Mr. Stromme was called away from the work, and it was not until the summer of 1912 that the mapping was continued by G. W. Crane. He also was called away from the work at the close of the year and during the seasons of 1913, 1914 and 1915 the field work was continued by the present writer, under instructions to secure data, not only relative to the glass sand deposits of the state, but also data regarding all other sand and gravel deposits of whatever nature which might be encountered, thus broadening greatly the scope of the original investigation.

Field Work.—During the summer of 1907, Mr. Stromme mapped in detail the distribution of the St. Peter sandstone between Missouri River and the Mississippi, from Becker through Pacific and Byrnesville to Festus and Crystal City, across portions of Franklin, St. Louis and Jefferson counties. The northern portion of this work had for its base the O'Fallon and DeSoto quadrangles. The southern portion of the area mapped by Stromme was not at that time covered by any topographic base, and it was necessary to place the geology on an old and very incomplete county map. The work here is somewhat generalized.

In 1912, Crane took up the unfinished work of Stromme, and mapped that portion of the St. Peter belt lying north of Missouri River, from Klondike to Mineola, across portions of St. Charles, Warren, and Montgomery counties. The O'Fallon, Hermann, and Fulton sheets furnished the topographic base for this work, which is done in as much detail as the unsatisfactory nature of the two latter sheets permit.

During the summer of 1913 the writer mapped the St. Peter across Cape Girardeau County, and north in Perry County as far as Brewer, about five miles north of Perryville. No topographic quadrangles are available in this area. The Soil Sur-

vey Maps of the U. S. Bureau of Soils were used as a base for this work. These maps show culture and drainage lines very accurately, and served as a fairly satisfactory base, the distribution of soils more than once being of value in locating boundaries.

From Crystal City south to Brewer in Perry County, the area is covered by the Weingarten, Crystal City, Renault, and Chester sheets, the three latter of which have just been issued, and which are excellent maps. The writer spent about three weeks in mapping this area, and the work was left to be completed by Dr. Stuart Weller, Mr. Mehl, and Mr. St. Clair, who are engaged in cooperative work in that area for the U. S. Geological Survey and the State of Missouri.

A few weeks was spent by the writer going over rapidly the areas mapped by Stromme, Crane, Mehl, and St. Clair, in order to collect samples and briefly note the economic aspects of the occurrences of the sandstone.

The remainder of the time was spent visiting the various sand producers of the State, taking samples of their output, studying the origin and occurrence of their deposits, methods of production and treatment, and market conditions.

Laboratory Studies.—With the exceptions noted in the text, the chemical analyses presented in this report were made by Mr. R. P. Rinker, analyist for the Bureau of Geology and Mines, and most of the screen mesh tests were made by G. F. Metz, also of this Bureau.

Determination of specific gravity and voids, a part of the screen tests, the computations of effective size and uniformity coefficient, and the dirt tests were made by the writer.

ACKNOWLEDGMENTS.

The writer is indebted to the various members of this Bureau for suggestions and cooperation in the work. Managers, superintendents, and other officers of the plants visited, invariably rendered all the assistance and information in their power. Especial thanks are due Mr. R. D. Killian of Perryville for the many courtesies rendered, while the writer was working in that vicinity.

CHAPTER I.

NATURE, ORIGIN AND PROPERTIES OF SAND.

DEFINITION OF SAND.

Sand is usually defined as any unconsolidated rock material coarser than clay or silt and finer than gravel. Gravel is any aggregate of rock particles coarser than sand and finer than boulders. From these statements it will be observed that there are no definite lines of demarcation between clay or silt and sand, between sand and gravel, or between gravel and boulders, each so grading into the next that the coarse sand of one classification may be the fine gravel of another. Usually material smaller than 0.1 to 0.2 of an inch in diameter is called sand rather than gravel by engineers.[1] Other authorities use one-fourth of an inch as the dividing size between sand and gravel. Although there is no definite or necessary chemical or mineralogical composition of sand, our usual conception of it involves a highly silicious, usually quartzose aggregate of grains; but the composition may vary through the complete range of all possible rock types. Sand differs from sandstone only in that the former is loose, the latter consolidated; consequently, there are all gradation from loose sand through friable sandstone to quartzite. And though we usually think of sandstone, like sand, as a quartzose aggregate, we sometimes have sandstones consisting largely or even wholly of substances other than quartz.

ORIGIN OF SAND.

Sand consists of small particles of rock which have resulted from the breaking down or weathering of other rocks. This weathering may be the result of either mechanical or chemical processes.

---

[1]Taylor, F. W., and Thompson, S. E., Concrete plain and reinforced, 2d ed., 1911. Sabin, L. C., Cement and Concrete, 2d ed., 1907.

SPINDLETOP ENGINEERING LIBRARY
LAMAR STATE COLLEGE OF TECHNOLOGY

MECHANICAL WEATHERING.

Mechanical weathering is brought about in many ways. In temperate and cold latitudes, the work of frost in this respect is very important. Water, held in the larger openings or in the minute pores of the rock near the surface, freezes and the expansion causes the rock to crumble into small particles. In those rocks, such as the granites, which are made up of a variety of minerals, the unequal heating and expanding of the various types of mineral grains, each with its own rate of expansion, cause them to tear away from their neighboring grains allowing the rock to fall into fine particles. This is particularly true in arid regions where the daily range of temperature is extreme. It deserts the abrasive power of wind-driven sands rapidly grinds away rock surface, forming more sand and powdering still more finely the blown particles. The abrasive effect of sand and pebbles on river beds and on each other, as well as the rasping of glaciers over their beds, also causes the grinding up of much rock material both from the beds and from the transported load. Waves too tend to grind up rocks, and the wedging power of growing roots is a considerable factor in the mechanical breaking up of solid rock into sand or gravel.

The most important characteristic of this mechanical weathering is that it yields a product chemically much like the parent rock from which it is derived. It is simply the same rock in finer particles. Granites and other igneous rocks weather mechanically to sand of the same chemical composition as the rocks themselves; sandstone simply breaks down to sand; limestone on account of its solubility does not usually reduce to sand; and shales and slates weather back to clay particles too fine in grain to be called sand. Not all the minerals of any given rock, however, are of equal hardness; consequently the continual wearing by wind, water, or ice grinds the softer minerals faster and finer than the hard. The finer the particles, the more easily they are removed by wind or running water. The result of this is a segregation of the harder minerals; and as quartz is the hardest of the abundant rock-forming minerals, there is a tendency for the segregation of quartz sands, even by mechanical weathering.

CHEMICAL WEATHERING.

It is rare, indeed, however, to find any weathering-product resulting from mechanical processes alone. With the exception of quartz, clay (chiefly kaolin), the iron oxides (limonite and hematite), and limestone (calcite and dolomite) most of the commoner rock substances are changed by the chemical activity of the atmosphere or ground water; that is, by uniting with certain elements from the air or water, they change their chemical composition and become different minerals. Some of these new minerals are soluble and are carried away in solution to lakes or the sea; some are insoluble and are left behind as residual products or are removed more slowly by mechanical means.

When an igneous rock, such as a granite, weathers chemically, the soluble minerals which are formed are carried away, the insoluble remain behind in the form of clay and quartz sand mixed with iron oxide and many minor constituents. These are intimately mingled, constituting a sandy clay or a clayey sand, depending on whether the sand or the clay is in excess; but as the clay is in a more finely divided state than the quartz sand, it is more easily carried away by wind or water. Thus chemical weathering like mechanical, only to a much greater degree, segregates quartz sand; and as igneous rocks vary greatly in the amount of quartz they contain, it follows that those highest in quartz (acidic rocks like granite) yield the largest amount of sand, those with little or no quartz (basic rocks such as gabbro) yield the smallest amount, while some rocks yield no sand whatever. The granites of southeast Missouri weather, partly mechanically, partly chemically, yielding a coarse sand made up of angular grains of quartz and feldspar (arkose or feldspathic sand). Since the feldspar weathers readily and the quartz very slowly, the farther the sand is carried along the streams, and the more it is worked over, the more of the feldspar weathers out and the higher the percentage of quartz left in the sand.

Because metamorphic rocks usually are not very different in chemical composition from the rocks from which they are derived, they will not differ materially from them in their weathering, except that they usually weather more slowly.

Sedimentary rocks, themselves the consolidated products of former weathering, are already more or less completely assorted, depending upon the conditions under which they were formed. The more completely chemical weathering had proceeded in the

first production of these sediments, the less change will it produce on the present rock mass. A sandstone containing still unweathered fragments of the original rock will be weathered chemically to a purer quartz sand than it was formerly, and a sandstone with a considerable admixture of clay will be more completely assorted upon weathering. Pure quartz sandstone, therefore, weathers to a pure quartz sand, an impure sandstone to a purer sand than it was before. A limestone, if pure, completely dissolves; if impure, the limestone itself is removed in solution, leaving the chief impurities, chert, sand, and clay as residuals. Most of the important chert gravels of the small streams of the Ozark region have resulted thus from the weathering of very cherty limestones. The clay being finer in grain than the sand or chert will be carried away more rapidly by wind, running water, or waves, thus again tending to segregate the quartz. In like manner, the finer clay of an impure shale will be carried off, leaving behind the purer quartz sand.

Thus it will be seen that the whole process of weathering and erosion is a selective one in which there is constant tendency to produce more and more thoroughly assorted sediments, the clays and silts being carried away, the purer quartz sands being left behind. These more or less theoretical conditions are presented as throwing light on certain principles of sand distribution. It may be stated as a general rule that the more times a series of formations have been worked over by weathering and erosion, the more thoroughly they become assorted. If, then, a series of sands rests directly upon a series of old crystalline rocks from which they have been derived, they may usually be expected to contain more unweathered constituents of the original rock than if they had been transported far, or worked over several times. Thus the St. Peter and Roubidoux sandstones are purer than the Lamotte, because they have been carried farther or worked over more times, or perhaps both. Similarly, by the process of selective transportation, the deltas of great slow-flowing rivers are made up of very fine silts, the lower stretches are full of rather fine sands, while in the upper reaches and along many of the tributaries, the sands are often coarse, grading up into gravels.

CLASSIFICATION OF SAND.

Sands may be classified on several different bases. Among those most commonly used are origin, chemical content, mineral content, geographic distribution, stratigraphic distribution, size, and use.

CLASSIFICATION BY ORIGIN.

On the basis of origin, sands may be classified as eolian, river, glacial, lake, or seashore deposits, according as they have been formed by wind, by river erosion, by glacial abrasion, in lakes, or along the beaches of the ocean. Volcanic sand, more properly known as tuff or volcanic ash, is the fine particles ejected from volcanoes. Coral sand is finely ground fragments of corals and shells. Most of the sands of Missouri are river and glacial in origin. A few may be beach deposits.

CLASSIFICATION BY CHEMICAL CONTENT.

Classified on the basis of chemical content, sands are ferruginous, calcareous, argillaceous, and silicious, according as they contain iron, calcium carbonate, clay, or silica in excess of the quantity found in average sand. Sands with sufficient iron to give an unusual reddish, yellowish, or brownish color are said to be ferruginous, although some sands which appear to be strongly ferruginous and which show a deep reddish color, contain as low as one-half of one per cent of ferric oxide. In such sands the iron is only a very thin coating over the grains; but where sands have a ferruginous cement, the iron content is likely to run higher. Sands containing only 3 per cent of calcium carbonate, that is, enough to result in marked effervescence, are called calcareous, though the calcareous sands of the Bermudas consist almost wholly of calcium carbonate, the result of the ceaseless grinding by the waves of vast quantities of marine shells and corals along the shore. This sand is also frequently known as eolian limestone or coral sand. Sand which contains an appreciable but indefinite amount of clay is argillaceous sand, which, by increase in the ratio of clay to sand, becomes an arenaceous or silicious clay or shale. The terms silicious sand and silica sand are usually applied only to those sands with an exceptionally high silica content. There is no unanimity of opinion regarding the usage of the term, but it is

more often than not restricted to sands ranging from 96 per cent to 100 per cent pure silica. The St. Peter sandstone is usually spoken of as a typical silica sand, though it is slightly ferruginous in places. Most of the river and glacial sands are moderately argillaceous. Missouri sands are usually but slightly calcareous. Sands with a considerable amount of bituminous matter are known as bituminous or asphaltic sands.

CLASSIFICATION BY MINERALOGICAL CONTENT.

On the basis of mineral content, sand may be named either from the dominant mineral present, or from the unusual occurrence of some particular mineral, even though the actual quantity of that mineral may be very small. Quartz sand, though other minerals may be present in small amounts, consists essentially of quartz. Most of the sands of this State are properly spoken of as quartz sands. Feldspathic sand, or arkose sand, may be largely quartz, with appreciable quantities of unweathered feldspars, or it may consist almost wholly of feldspar, depending on the nature of the rock from which it has been derived. Feldspathic sands are common in the granite regions of southeast Missouri. Micaceous sand is so called from the presence, usually in only small quantities, of flakes of mica. Magnetite sand, or magnetitic sand as it is sometimes called, may be any type of sand with an appreciable amount of magnetite (magnetic iron ore). Such sands are frequently known as "black sands," and though usually carrying only a little magnetite, they may in rare cases be almost pure magnetite. Any sand with considerable quantities of unweathered ferromagnesian minerals is known as a ferromagnesian sand. Such sands usually result from mechanical disintegration of basic igneous rocks. Sands carrying the mineral glauconite, a complex greenish silicate of iron and potash, and common on the Atlantic Coastal Plain, are known as glauconite sands, or more commonly as "green sands," from the greenish color imparted by the glauconite grains which may make up as high as 75 per cent or more of the mass. These sands, on account of the potash and phosphoric acid they contain, are used as fertilizer. Monazite sands, carrying the valuable rare-earth phosphate, monazite, result from the weathering of monazite-bearing igneous rocks. Auriferous sands and gravels are those carrying placer gold. Black sands, green sands, monazite sands, and gold-bearing sands are practically unknown in this State.

CLASSIFICATION BY GEOGRAPHIC DISTRIBUTION.

On a geographic basis, sands or gravels are often named from the locality from which they come. Thus we speak of Mississippi River sands, Missouri River sands, Kaw River sands, Platte River sands, Meramec River sands, Meramec River gravels, and others. To sand dealers and consumers such names have a considerable trade significance, because they stand for certain definite qualities characteristic of sands or gravels from these localities.

CLASSIFICATION BY STRATIGRAPHIC DISTRIBUTION.

Sands are not infrequently named from the formation or geologic age in which they occur, as, for example, St. Peter sand, Lafayette gravel, Tertiary gravel, Quaternary sands and gravels, Pleistocene sands and gravels, Aftonian gravels, Recent sands and gravels. Like locality names, stratigraphic names may have a commercial value. This is especially true of the St. Peter sand, the name having come to stand widely for purity and whiteness as well as for certain other well known, and perhaps over emphasized, St. Peter characteristics.

CLASSIFICATION BY SIZES.

Civil Engineers, architects, and builders are particularly interested in size of grain, and tend to classify sands according to size. Condra[1] recognizes three sizes as follows:

Table of sizes given by Condra.

Fine sand	0.5,	mm. or	0.02	inch	in	diameter.
Medium sand	2.0,	" "	0.08	"	"	"
Coarse sand	5.0,	" "	0.20	"	"	"

In gravels, the following widely used terms are partly indicative of size, partly of use:

Table of sizes in common use in Missouri.

Sand	Through	$\frac{1}{8}$	inch			
Torpedo gravel	"	$\frac{1}{4}$	"	on	$\frac{1}{8}$	inch; also called torpedo sand.
Roofing	" "	$\frac{3}{4}$	"	"	$\frac{1}{4}$	"
Binder	" "	$1\frac{1}{2}$	"	"	$\frac{1}{4}$	"
Concrete	" "	$2\frac{1}{2}$	"	"	$1\frac{1}{2}$	"

[1]Condra, G. E., Sand and gravel resources and industries of Nebraska; Nebraska Geol. Survey, vol. 3, Pt. 1, p. 29, 1908.

These sizes are not entirely fixed, but are those used by one of the largest producers in the State. Modifications of these are known as coarse torpedo, fine roofing, coarse roofing, etc.

CLASSIFICATION BY USES.

According to use, sands and gravels are given a variety of names, such as concrete gravel, roofing gravel, plastering sand, paving sand, glass sand, moulding sand, core sand, filter sand, furnace sand, stone sawer's sand; terms which explain themselves. A detailed description of these will be taken up in a separate chapter devoted to a discussion of the uses of sand.

PROPERTIES OF SAND.

Upon the physical and chemical properties of sands, depends their suitability for the various uses to which they may be put. For some uses the physical properties are controlling factors, for others the chemical composition is the most important.

COLOR.

For most uses color itself is a negligible factor and needs to be taken into consideration only in a few special uses. Iron, one of the commonest impurities, is usually present as a coating on the individual grains, and even in very small amounts gives to the sand various shades of red, yellow, or brown, grading in some cases almost to black. The presence of clay or shale gives colors varying from gray to pale green. A number of dark colored minerals (tourmaline, garnet, pyroxenes, amphiboles, magnetite, etc.) give grayish, mottled colors, ranging to black in the so called "black sands." Such mottled shades are seen in Missouri and Mississippi river sands, and in the glacial sands. In sandstones the commonest discoloration is reddish, yellowish, or brownish iron stain, or gray-green clayey bands. The purer quartz sands vary from very light gray to an almost dazzling white. In the manufacture of certain light-colored terra cotta and for use in cement or mortar where great whiteness is desired, pure white sands are demanded. In the manufacture of high grade glass also only the whitest sands are used, though colored sands are sometimes employed in the cheaper grades. Color is considered in selecting sands largely because it is an indication of impurities. The St. Peter is the whitest sand available in this State.

CLEANNESS.

A much more important property of sand than color is cleanness, a term used rather loosely to indicate purity. Technically, cleanness is determined by washing. A given amount of sand after being completely dried and weighed is placed in a pan of water and thoroughly stirred. It is then allowed to settle a given length of time, after which the water is poured off. This process is repeated as often as is necessary to wash the sand clean, that is, until the water when stirred ceases to show any turbidity. The washed sand is then dried and again weighed. The loss of weight, which is found by subtracting the weight after washing from the weight before washing, represents the removed impurities; and this difference divided by the original weight (before washing) gives the proportion of impurity in the unwashed sand. This is expressed in the formula:

$$D = \frac{W - W'}{W}, \text{ in which}$$

D = the proportion of dirt,
W = the weight before washing, and
W′ = the weight after washing.

Of course, the sand must be thoroughly dried when weighed, as moisture would increase the weight. In order to make this figure for "D" of greatest value in comparing sands, it is necessary to know the length of time the sand was allowed to settle in the water, for this will control the amount and coarseness of the material removed. This length of time should always be stated in giving percentage dirt. In pouring off the turbid water, care must be exercised not to pour off sand grains, as this would increase the amount of apparent impurities. It is usually best to evaporate the last portion of water rather than to try to pour off too closely.

From a study of this method of cleaning sand, it will be seen that the chief impurity eliminated is clay or silt, together with a little woody or organic matter and a little finely divided quartz. Some iron stain is also removed. In most of the glass sands (St. Peter sandstone) the percentage of dirt is so low as to be almost inappreciable by this method, though a few of the producers find it desirable to wash their melting-sands. In this way they remove a slight clay sediment and a portion of the iron, together with much very fine quartz sand which is undesirable in the batch. Many gravels are washed to remove

the clay, but this washing is done by rapid currents of water which remove fine sand as well. Practically all of the river sands are dredged by means of centrifugal pumps. The overflow from the barge carries off much clay, silt, fine sand and lignitic matter. Most of the sands receive no further washing. The field work on the river sands was done during the season of high water, when it was impossible to collect samples directly from the bars. Most of the samples taken had been washed through the pumps, so that tests for percentage dirt would mean little, except to show in what condition the sand is actually placed on the market. One Missouri River sand taken directly from the bar was washed as indicated above. It was shaken vigorously in a test tube, and after shaking was allowed to settle one minute. It took ten washings before the water ceased to show appreciable turbidity. The loss by weight was 2.88 per cent. By ordinary inspection, this sample showed the most dirt of any Missouri or Mississippi River sand sampled.

Mississippi sand washed through the pump showed a maximum of 2.3 per cent dirt and a minimum of 0.3 per cent. Missouri sand, washed through the pump, showed 1.1 to 0.38 per cent.

Bank sand from the Tertiary in southeast Missouri varies from 0.6 to 27 per cent dirt, and the glacial sands of north Missouri show a high dirt content, the best selected samples running about 5 or 6 per cent, while samples chosen at random run much higher.

A simpler method than that just outlined to detect impurities in the sand is to rub a little of it between the hands. A quartz sand that is perfectly clean will not soil the fingers. If a sand is found to be dirty, an examination should be made of the character of the dirt. Clay in moderate quantities (ten to thirty per cent of the sand) is said not to materially weaken cement mortars. Sabin[1] sums up conclusions based on numerous tests, as follows:

"Neat cement and rich mortars are injured by the addition of clay, the rate of hardening and the ultimate strength being diminished. Lean mortars containing three to four parts sand to one cement are usually improved by the addition of clay to the amount of 40 to 100 per cent. of the cement, or 10 to 25 per cent. of the combined weight of cement and sand, and the ability of such mortars to withstand early immersion may be greatly enhanced by such additions. It is evident from the above tests that the expense which should be incurred in washing sand to remove a small percentage of clay is limited, and for certain uses there is no question that mortar may be improved by the addition of clay."

[1]Sabin, L. C., Cement and concrete, 2d ed., p. 182, and p. 271, 1907.

Again, the same writer says:[1]

"The clay is apparently expressed as the per cent. of total aggregates. It is seen that while six to twelve per cent. clay retards the hardening of both Portland and natural cement concrete, the strength of the Portland concrete after four weeks is increased by six per cent. clay, while at the same age the strength of the natural cement concrete is not greatly affected. The ramming of concrete is facilitated by the presence of a small amount of clay, but larger amounts may render the mass sticky and difficult to ram."

The same authority also states that calcareous marl is usually not particularly harmful in cement work, but peaty matter, humus, or badly decayed rock particles, particularly those that flake into thin scales, are very detrimental as they materially decrease or even destroy the strength of mortar. Peaty or lignitic matter, which is rather prevalent in Missouri River sands, swells, due either to heat or to moisture, and causes the surface of walls or sidewalks to pop open, leaving pits. Builders claim, however, that the lignite does not seem to be harmful in heavy walls or foundations. On the other hand, vegetable matter present in the form of humus, coating the grains of sand and preventing the proper adhesion of the cement, may possibly be harmful when present in quantities as small as ½ per cent of the weight of the sand,[2] and are certainly harmful when abundant. Of course, the surface of the individual grains of sand or gravel should be free from any other coating, clay, for example, which would prevent proper adhesion of the cement to the rock particles.

SIZE OF GRAIN.

Size of grain is of considerable importance in determining the value of a sand for certain purposes. This sizing is usually determined by screen tests.

SCREEN TESTS.

The screen tests carried on in this investigation were made with screens of the W. S. Tyler Company, of Cleveland, Ohio. The sands were passed through 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 150, and 200-mesh screens. Because there is no uniformity in the size of opening for a given mesh in screens put out by different companies, the name of the screens used and a

[1]Op. cit., p. 319.

[2]Taylor, F. W., and Thompson, S. E., Concrete plain and reinforced, 2d ed., pp. 154b and 154c, 1911.

table of the sized openings for each mesh, as published in the catalog of the company, are given.

Table of screen meshes used.

Mesh.	Diameter of wire in inches.	Diameter of opening in millimeters.
10	.035	1.651
20	.016	.864
30	.0135	.503
40	.010	.381
50	.009	.279
60	.008	.221
70	.007	.185
80	.00575	.173
90	.00525	.150
100	.0045	.140
150	.0026	.104
200	.0021	.074

The necessity for this is indicated by the following quotation from the catalog of the Tyler Company:

"In a technical sense, the word 'mesh' is meaningless, unless the diameter of the wire is also given, so that the opening is determined."

The method of using the screens is indicated by the following suggestions also taken from the Tyler catalog:

"To save time in testing it is well to place the various sieves to be used in one nest, the coarsest opening at the top of the nest. Place sample to be screened in the top sieve. The sieves can be roughly shaken in this method and as the product works down through the finer sieves, they will not be overloaded and a quick separation [will be] obtained. After shaking the sieves roughly, each sieve should be shaken separately over a pan to make sure the separation is complete. The sieves should be shaken anywhere from four to ten minutes, the time varying as to the fineness and quantity of the product, also to the amount of screen surface in the sieve."

In all the mesh tests made for this report, the method just given was followed. Another caution suggested by the Tyler catalog is as follows:

"Great care should be taken not to lose any of the product in the testing process, however, the loss cannot be entirely eliminated. There are three methods in common practice of overcoming this small percentage of loss. One is to start the test with a sample with from one to three grams overweight. By experience this quantity can be very definitely determined so that the final quantities will show 100, 250, 500, or 1000 grams as required. The larger the sample, the larger the loss will be, so that if a sample weighing 1000 grams be used, it would be well to start with 1003 grams. Another method is to divide the loss in proportion to the weight of the different products. Still another method is to assume that the loss is in the fines, i.e. the minus 200-mesh product."

In all tests presented in this paper, the second correction was applied, the whole being recomputed on the basis of 100 per cent. The following actual example shows the method used:

Table showing method of recomputing screen tests.

(Weight of sample, 100 Grams.)

Through.	On.	Weight.	Re-computed to 100 per cent.
—.....	10	2.10	2.12
10.....	20	4.80	4.84
20.....	30	13.05	13.16
30.....	40	31.65	31.92
40.....	50	27.30	27.52
50.....	60	13.70	13.82
60.....	70	3.60	3.63
70.....	80	1.50	1.51
80.....	90	0.40	0.40
90.....	100	0.55	0.56
100.....	150	0.25	0.25
150.....	200	0.27	0.27
200.....	pan	0.00	0.00
		99.17	100.00

The loss was 0.83 grams on a 100-gram sample, or a little less than 1 per cent. By a recalculation to a basis of 100 per cent, this loss was proportionately distributed throughout the different meshes. The proportionate change is so slight, however, as to be practically negligible for tests of this character.

In making the screen tests on those sands existing in the form of sandstone it was necessary to crush the rock. In doing this possibly a certain amount of crushing of individual grains resulted. Care, however, was taken to avoid this and most of the samples were crushed with a flat spatula, though a few had to be ground in a mortar. As any powder thus produced may have added to the fines, the minus 200-mesh product may be slightly excessive; and as it was almost impossible to separate entirely the individual grains, the coarser product usually contained a small percentage of aggregates of grains. Consequently, it is possible that the plus-20 and the plus 30-mesh product may also be slightly too large. It is thought, however, that these errors are scarcely of sufficient magnitude to affect the general conclusions based on the screen tests.

Of course, in the case of all sands dredged with centrifugal pumps, much of the finest material passes off with the overflow from the barges, and so the mesh tests on such sands do

not show the normal amount of fines which might be expected from bar-run samples.

According to the Bureau of Standards,[1] practically all the sand for plaster work should pass a 20 or 30-mesh, for mortar a 10-mesh, and for fine concrete aggregate, a ¼-inch mesh.

A large number of these sieve tests were made, results of which are given under the discussion of sands by formations and districts.

UNIFORMITY COEFFICIENT.

This is a term used to designate the amount of variation in size of sand grains. It is defined[2] as the "ratio of the size of grain which has 60 per cent of the sample finer than itself to the size which has 10 per cent finer than itself."

That is, in a sand, if just 10 per cent were finer than 1mm. and just 60 per cent finer than 2mm., the uniformity coefficient would be 2. In other words, fifty per cent of the sample lies between 1mm. and 2 mm. in diameter. Similarly, if 10 per cent of the sample were finer than 3 mm. and 60 per cent finer than 6 mm., the uniformity coefficient would again be 2, though the latter sand would be three times as coarse as the former. Thus, it will be seen that the uniformity coefficient does not necessarily indicate the absolute coarseness or fineness of a sand. It merely expresses a ratio of variation of size of grain. A sand with a coefficient of 5 means that 50 per cent of that sand has a variation in size of grain represented by the ratio of 1:5. A uniformity coefficient of 1, which is almost an impossibility, would mean that 50 per cent of the sand was uniform in size, with 10 per cent smaller and 40 per cent larger than this size. The smaller the uniformity coefficient, the more uniform the grain of the sand; the larger the uniformity coefficient, the less uniform the grain of the sand.

In the following table is given the screen test of a sample of St. Peter sand, and following that (Fig. 1), the plot of a curve showing the derivation of the uniformity coefficient. (Facing page 15.)

---

[1]Circular No. 45, pp. 35-36, 1913.

[2]Condra, G. E., Sand and gravel resources and industries of Nebraska; Nebraska Geol. Survey, vol. III, pt. 1, p. 30, 1908. See also Slichter, C. S., Motion of underground waters; U. S. Geol. Survey, Water-Supply and Irrigation Paper, 67, p. 22, 1902.

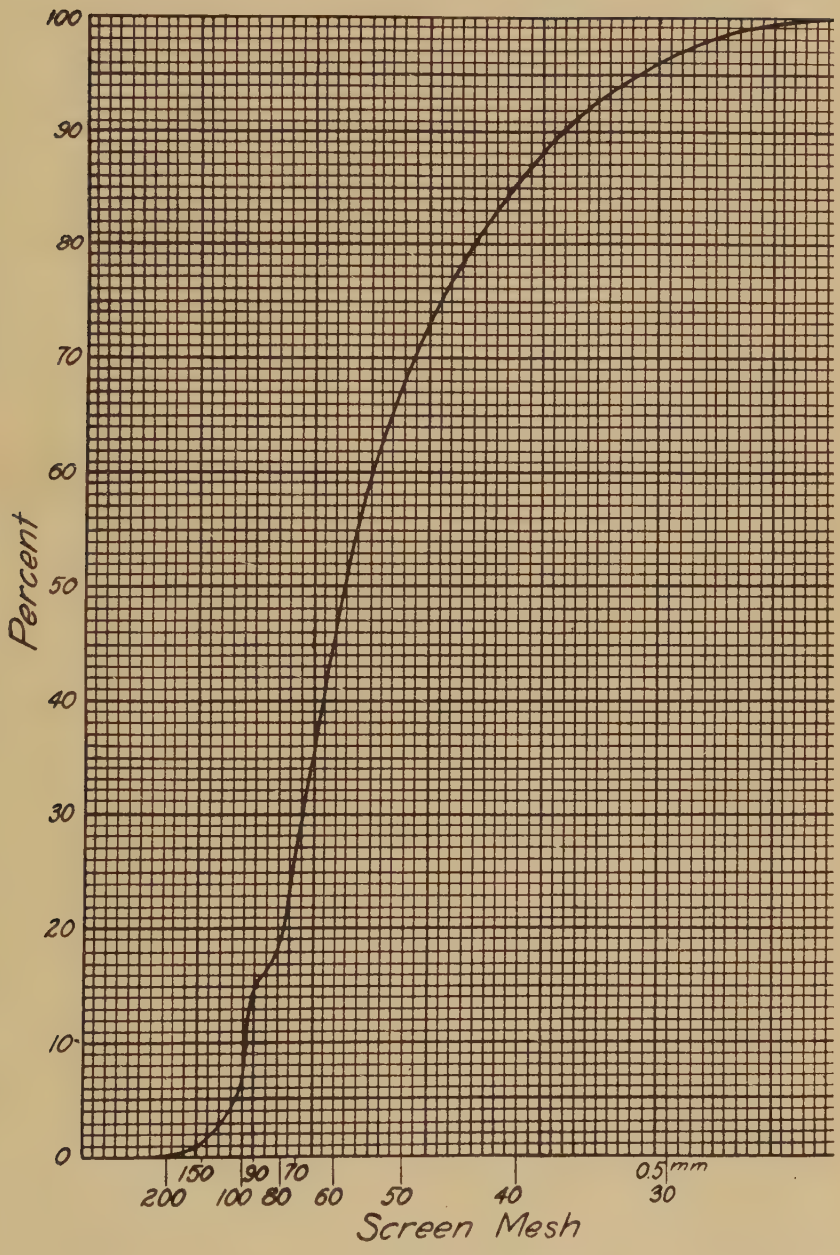
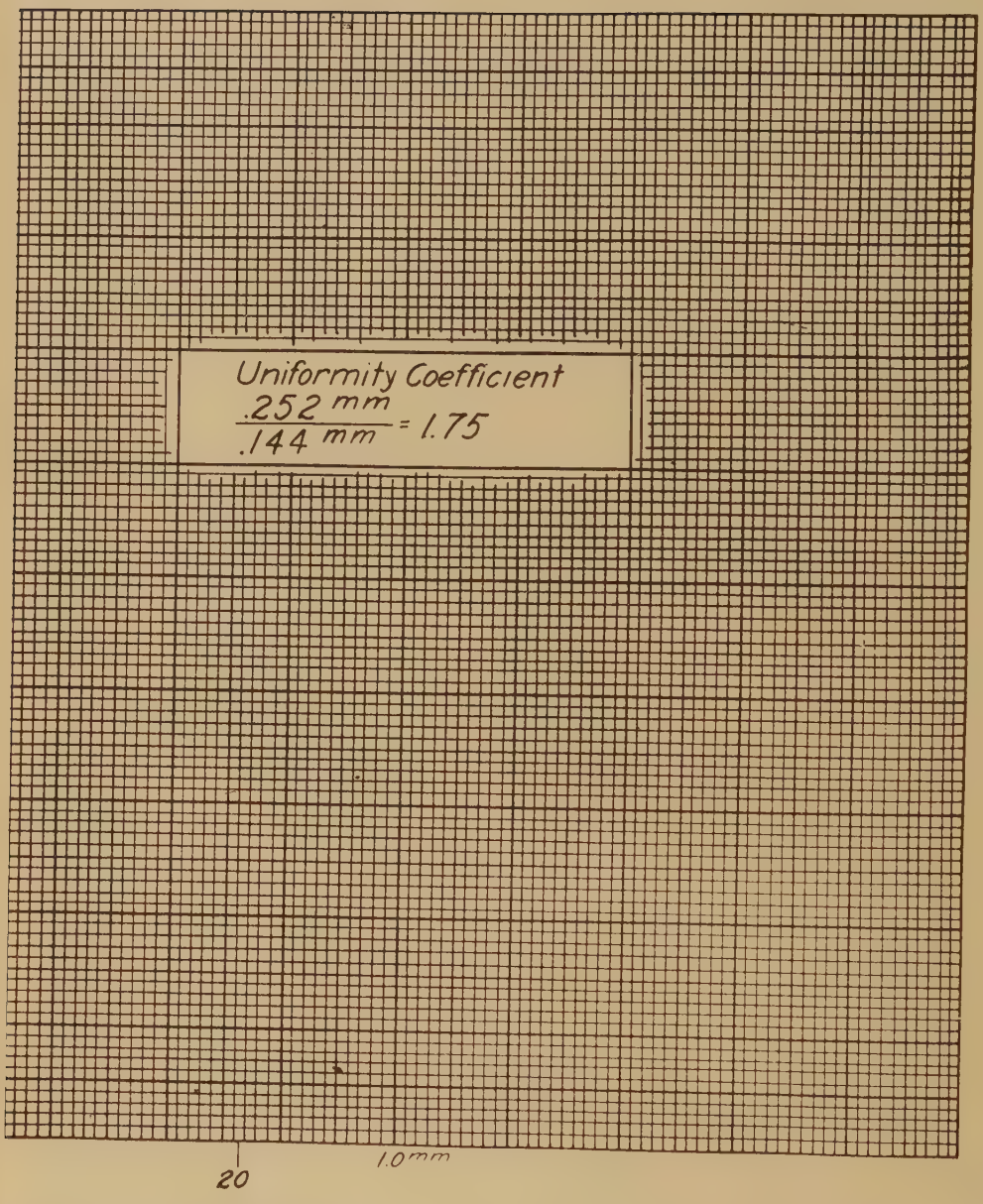


Fig. 1. Plat show



ing derivation of uniformity coefficient.

Table showing derivation of uniformity coefficient.

Through.	On.	Per cent.	Mesh.	Opening.	Total thru.	Total on.
—.....	10	——	10	——	100.00	0.00
10.....	20	——	20	.864mm	100.00	0.00
20.....	30	3.71	30	.503	96.29	3.71
30.....	40	10.39	40	.381	85.90	14.10
10.....	50	17.42	50	.279	68.48	31.52
50.....	60	24.11	60	.221	44.37	55.63
60.....	70	14.72	70	.185	29.65	70.35
70.....	80	10.39	80	.173	19.26	80.74
80.....	90	4.22	90	.150	15.04	84.96
90.....	100	8.68	100	.140	6.35	93.65
100.....	150	5.66	150	.104	0.69	99.31
150.....	200	0.31	200	.074	0.38	99.62
200.....	Pan	0.38	Pan	——	0.00	100.00

Inasmuch, as the variation in size of sand grains is itself not a uniform one, the drawing of a smooth curve through the points of the plot introduces error, which is decreased, however, in proportion to the number of points actually located on the curve. That is, the larger the number of screens used in making the test, the more accurate will be the figure for the coefficient of uniformity.

Uniformity coefficient is a term much used in describing filter sands. For most other uses to which sand is put the figure is not usually considered. Generally speaking, sands with a low coefficient of uniformity are desirable for filter purposes and those with a high coefficient, for concrete work. The coefficient has been computed for most of the sands studied, and will be found under the separate description of each sand. The coefficient for Missouri sands was found to vary between 1.43 and 13.11, with an average of 1.75 for the St. Peter sand and about 2.37 for river sands, as placed on the market. Gravel screenings showed coefficients usually varying between 3 and 8.

EFFECTIVE SIZE.

The term effective size is defined[1] as a size "such that 10 per cent of the material is of smaller grains, and 90 per cent is of larger grains than the size given." That is, if 10 per cent of a sand passed a 1 mm. screen and 90 per cent were retained on the screen, 1 mm. would be the effective size. As effective size is one of the factors used in determining the uniformity

[1]Condra, G. E., Sand and gravel resources and industries of Nebraska; Nebraska Geol. Survey, vol. III, pt. 1, p. 31, 1908. See also Slichter, C. S., U. S. Geol. Survey, Water Supply and Irrigation Paper, 67, p. 22, 1902.

coefficient, this, together with the uniformity coefficient, defines rather closely the size and uniformity of a sand, and where effective size is also shown, the coefficient of uniformity means much more than it otherwise would.

Coarse sands are more satisfactory in concrete work, because each grain has a larger surface to which the cement coating may adhere, and actual tests show that mortars made of coarse sands have greater strength than those made with fine.[1] Since in natural aggregates coarse sands are usually less uniform than fine ones, it follows that aggregates with a high uniformity coefficient are more desirable, both because they are coarser and because they have a lower percentage of voids. Taylor and Thompson[2] conclude that,

"Sand with a uniformity coefficient above 4.5 is a good coarse sand for concrete work, and in comparing different natural sands the one having the highest uniformity coefficient may be considered the best.

"As in ordinary bank sand the size of the particles at the 10% line (which is termed the effective size) does not greatly vary, the diameter at the 60% line alone is a very good indication of the coarseness of the sand. A knowledge of the effective size and the uniformity coefficient of any sand enables one accustomed to mechanical analysis diagrams to form a picture of its character."

The effective size of Missouri sands was found to run as low as 0.1 mm. and as high as 0.51 mm., with an average of about 0.16 mm. for the St. Peter sands and about 0.25 for the river sands as placed on the market. It is to be noted that the uniformity coefficient of these sands is lower than the figure suggested by Taylor and Thompson. The effective size is large, however, and the sands are as coarse as the average building sands from many other localities. According to Condra[3] 80 per cent should be retained on the 74-mesh screen. As a matter of fact, from 50 to 80 per cent of most of the building sands of this State are retained on a 50-mesh sieve. The effective size of the important sands of the State will be found under the detailed descriptions by formations and districts.

FORM OF GRAIN.

Sand is usually spoken of as sharp or round, depending upon the degree of its angularity. Angularity may be due to crystal form, cleavage, or to crushing of grains. In natural sands,

[1] Sabin, L. C., Cement and concrete, 2d ed., pp. 173-174, 1907.

[2] Taylor, F. W., and Thompson, S. E., Concrete, plain and reinforced, 2d ed., p. 182, 1911.

[3] Sand and gravel resources and industries of Nebraska, Nebraska Geological Survey, vol. III, pt. 1, p. 150, 1908.

crushing usually plays but a small part in producing sharpness of grain. Quartz, which is the chief mineral of most sands, has practically no cleavage, and is rarely found crushed in nature. In general, its angularity, therefore, depends on its crystal form. On the other hand, feldspars have very perfect cleavage, a factor responsible in part for angularity in feldspathic sands.

Crystal form, which is responsible for the angularity of most sands, may be the crystal outline still retained by the quartz grains from their first crystallization from a cooling magma into an igneous rock. Constant attrition during the processes of weathering and erosion rounds these crystal angles, and long transportation may remove all traces of the original outline. As long transportation also sorts out impurities, as described in a previous section, it follows that the purer sands are likely also to be the more completely rounded. This is a particularly marked feature of the St. Peter sandstone.

It may happen that rounded quartz grains may be enlarged by the deposition of new silica. When this occurs, the added material usually restores the lost crystal form to the grains, making the sand again angular. This process is known as quartz enlargement. It can often be detected under the microscope by a thin film of ferruginous or other stain within the new crystal boundary, which marks the outline of the old rounded grain. It is thought that the greater angularity of the Roubidoux over the St. Peter is due in part to such re-crystallization.

As a rule, sharp sand has been considered more desirable than round for structural purposes, because it would hold better to the cement or lime. The belief is growing, however, that sharpness of grain is not so important, and according to the Bureau of Standards,[1] round sand is as good as sharp sand.

Smoothness or roughness of grain is quite as important as sharpness or roundness. A grain whose surface is rough and pitted will allow lime or cement to cling to it much better than will a thoroughly polished grain. As rounding and polishing are apt to go together, a condition so well shown by St. Peter sandstone, it may perhaps be the smoothness of rounded grains rather than their lack of angularity that is objectionable. Sabin[2] says,

"There is little question that if two samples of pure quartz sand, differing in sharpness but alike in all other respects, including percentage of voids, were tested side by side, the rounded grains would be found inferior."

[1]Circular No. 45, p. 36, 1913.
[2]Sabin, L. C., Cement and concrete, 2d ed., pp. 169-170, 1907.

If rounded grains are disadvantageous, other properties of the sand may readily counterbalance this disadvantage. The surface of the sand grains should also be clean and free from any film of impurities that might weaken the hold of the lime or cement.

It is to be noted that a sand with angular grains has a higher percentage of voids than one with the same sized round grains.[1] The lower percentage of voids of round grains may in part compensate for the smaller degree of sharpness. Unfortunately, there is no unit or quantitative standard of angularity; the value of a statement that a certain sand is round or sharp depends, therefore, on the experience and judgment of the man making the statement.

SOUNDNESS OF GRAIN.

Even more essential than the form of grain is the soundness of grain. Each individual grain should be at least as resistant both to tensile and crushing strength as is the cement used to bind the aggregate together.

"One of the most essential features of a good sand is that the grains should be perfectly sound. Evidences that chemical decay is going on in the grains would indicate that the sand is of a very inferior quality."[2]

SPECIFIC GRAVITY.

The specific gravity of a sand is dependent on the specific gravity of the constituent minerals. By far the most abundant mineral of an average sand is quartz, the specific gravity of which varies from 2.653 to 2.660. The presence of minerals of greater or less specific gravity somewhat modifies this figure. Flint, or chert, which is a common variety of quartz in many sands, and which may become a notable constituent of the sands from many Ozark streams, has a specific gravity of 2.60 to 2.64 and its presence in quantity tends to lower slightly the specific gravity of many Ozark sands and gravels. Decayed grains of chert in sands being often porous, the specific gravity of some chert sands runs particularly low, as a result of air included in the minute pores of the rotted chert. Sands containing lignite also run low, as lignite has a gravity of only 1.15 to 1.3. The specific gravity of the feldspars varies between 2.5 and 2.9,

[1]Taylor, F. W., and Thompson, S. E., Concrete, plain and reinforced, 2d ed., pp. 161, 162, 1911.

[2]Sabin, L. C., Cement and concrete, 2d ed., p. 169, 1907.

while orthoclase, the most abundant variety, has a specific gravity of 2.57. Highly feldspathic sands will, therefore, often run lower than quartz sands, though they may sometimes run higher when the more basic members of the plagioclase feldspar series are present. Kaolinite, the chief constituent of clay, has a gravity varying between 2.60 and 2.63; consequently, very argillaceous sands run slightly lower than pure quartz sands. Hematite (sp. gr. 4.9 to 5.3) and limonite (sp. gr. 3.6 to 4.0) occur usually only as a thin film or coating on the grains, but their presence in considerable quantities may appreciably increase the specific gravity of the sand. As a rule, however, the percentage is low, being less than 1 per cent in the most ferruginous sand examined from the glass sand formations. Few other sands were analyzed. Theoretically one per cent of hematite would increase the specific gravity of a pure quartz sand about 0.015, raising it from 2.66 to 2.675. Magnetite (sp. gr. 5.168 to 6.180) occurs abundantly in the so-called magnetite sands in which the specific gravity invariably runs rather high. Calcite has a specific gravity of 2.714, only slightly above quartz, and when present as a cement, is usually not in sufficient quantity to modify the specific gravity appreciably. Beach sands, however, with abundant shell fragments, made up of calcite, run higher than pure quartz sands. Among the so-called ferro-magnesian minerals, are several with specific gravities ranging around 3.10 to 4.30, and when present in quantity these raise the specific gravity of sand.

A method tried in the laboratory of this Bureau for determining the specific gravity of sands is as follows: A sample was thoroughly dried and weighed. Into a graduated tube was poured a measured volume of water. Into this water was poured the sample of sand. The mixture was then thoroughly shaken in the tube to be sure that all the voids were filled with water, and that no air adhered to the individual grains. The total volume of the mixture, less the original volume of the water, represents the actual volume (exclusive of voids) of the sand added to the mixture. The weight in grams divided by this volume (in cubic centimeters) gives the specific gravity of the sand. The solution is expressed by the formula:

$$\text{Sp. gr.} = \frac{W}{Vt. - Vw.,} \text{ in which}$$

W = the weight of the dry sand expressed in grams,

Vw = the volume of the water in the tube expressed in cubic centimeters, and

Vt = the total volume of the sand and water in the tube expressed in cubic centimeters, whence

Vt-Vw = actual volume of sand, exclusive of voids.

In the above described tests samples of about 100 grams weight were used and weighed to a milligram. The graduate was read to 1 cc. and an attempt was made to interpolate to tenths. Experiment showed that one-tenth of a cubic centimeter made a difference of approximately 0.01 in the specific gravity, and it was found impossible to read the volume much more closely than 0.3 of a cubic centimeter. Successive tests on the same sand showed variations of from 0.01 to 0.06, and this was considered too large an error. To correct this, a le Chatalier bottle graduated to tenths of a cubic centimeter, was employed. This differs from the ordinary graduated tube, in not being of uniform size. The lower part, where the sands accumulate is large, but the neck is narrow and long, where the graduations are marked. This gives the added capacity of a larger graduate, with the more sensitive readings of a small tube. The formula given above applies equally to this method.

By this means each of a dozen sands was subjected to several tests with results that differed at most by about two in the second decimal place. This is considered about as close work as is practical with sands, and forms a fairly satisfactory basis for determinations of voids by the specific gravity method. Dirty sands, or those that were ferruginous, gave much difficulty in reading the meniscus, and for such the le Chatelier bottle was not at all satisfactory. For these dirty sands, a picnometer bottle was used. This is a small globular shaped bottle, with a perforated glass stopper. When the bottle is filled with water, and the stopper inserted, the water rises and slightly overflows from the perforation thus insuring that the bottle is always filled to the same point. The weight of the bottle and the weight of water it contains when full are usually furnished by the maker, but may be determined by the operator. For particular work all weights are taken at a known temperature, and temperature connections applied, but for work on sands, this is not necessary. After the weight of the bottle, empty and full of water, has been determined, a known weight of sand is placed

in the bottle and the bottle filled with water, care being used to eliminate all bubbles. The whole is then weighed. The specific gravity is determined by the following formula:

$$\frac{Ws}{(Ws+Wb)-Wt} \text{ Sp. Gr., in which}$$

Ws = the weight of the sand (in grams.)

Wb = the weight of the bottle filled with water only (in grams), and

Wt = the total weight of the bottle with sand and water (in grams), whence

Ws + Wb = the total weight of the substance involved and

(Ws + Wb) − Wt = the weight of the water displaced; and hence its volume.

Successive determinations of the same sample by this means invariably checked to five in the third decimal place.

Specific gravity is a property little considered in the practical use of sands. It may be said, however, that any considerable variation from 2.65 in the specific gravity of a sand points to impurities or to porosity of the individual grains, and gives some hint as to the chemical properties. A large number of tests show the specific gravity of Missouri sands to range between 2.42 and 2.66. The detailed results of these tests will be given under the description of sands by formation and districts.

VOIDS.

Because the grains of a sand do not fit together perfectly, there is within the sand a certain amount of empty space, known as pore space, or voids. The size of the individual voids is large in a coarse sand, small in a fine sand. In a sand of perfectly uniform-sized grains, the porosity is independent of the size of grain. A sand all of whose grains just pass a 20-mesh screen has the same porosity as one all of whose grains just pass a 60-mesh screen, provided the grains in both instances are of the same shape and are arranged similarly. With perfectly uniform-sized spherical grains, porosity varies between a minimum of 25.95 per cent and a maximum of 47.64 per cent[1]. In practice, however, it has been found almost impossible so to arrange such a sand that it will show less than 44 per cent voids.[2]

[1]Slichter, Charles S., Motions of underground water; U. S. Geol. Survey, Water-Supply and Irrigation Paper, 67, pp. 19-21, 1902. Also U. S. Geol. Survey, Nineteenth Ann. Rept., pt. 2, pp. 305-310, 1899.

[2]Taylor, F. W., and Thompson, S. E., Concrete, plain and reinforced, 2d ed., pp. 168-169, 1911.

The more uniform the size of grain, the more nearly will it approach the computed theoretical value for any particular type of arrangement; the less uniform the size, the less will be the actual observed pore space. The reason for this is that in a sand which is not uniform, the small grains often lie wholly within the voids between the larger grains, in this way reducing the theoretical pore space. The smallest percentage of voids will occur with a mixture so graded that the voids of each size will be occupied by the largest grains that will lie wholly within them. As most coarse sands in nature are less uniform than finer sands, they frequently have lower voids. This is not, as is often stated, because the sand is coarse, but because it is not uniform in size. The high porosity of uniform sands, as compared with that of sands not uniform, is responsible for the demand for sands with a low uniformity coefficient for filter purposes and for thoroughly graded and properly proportioned aggregates in concrete, because lack of uniformity or a high uniformity coefficient is associated with low pore space, and a consequent decrease in the amount of cement necessary in the mixing of the concrete. It is also to be noted that

"Materials with round grains, such as gravel, contain fewer voids than material with angular grains, such as broken stone, even though the particles in both may have passed through and been caught by the same screens."[1]

There are several methods in use to determine the voids in unconsolidated sands. The following was the first method to be tried in the laboratory of this Bureau. Into a large graduated tube a measured volume of water was poured. In another large graduated tube was measured a quantity of sand, thoroughly dried at 110° C. In measuring this sand it should be allowed to fall slowly into the tube, and should be leveled off carefully without shaking down the sand. This gives the volume dry and unpacked. This measured volume of sand should then be poured into the measured water in the first graduate, slowly enough to wet all the individual grains and to fill the pores thoroughly with water, being sure that there is sufficient water to completely cover the sand, and to leave a measureable excess over the top of the sand. The bottom of the tube must be tapped until the sand is so compacted that several vigorous taps make no appreciable difference in the level of the top of the sand. Read the total volume of the mixture, that is, the

[1]Taylor, F. W., and Thompson, S. E., Concrete, plain and reinforced, 2d ed., pp. 160-161, 1911.

surface of the water in the tube. Read also the surface of the sand; in other words, the volume of the sand including pore space. It is evident that the porosity of the loose dry sand measured in the first tube will be greater than that of the packed wet sand measured in the second tube. To get the porosity of the packed wet sand, the following formula may be used:

$$\text{Voids} = \frac{Vw-(Vt-Vs),}{Vs} \text{ in which}$$

Vw = volume of the water in the tube, before adding sand,
Vt = total volume of sand and water in the tube,
Vs = volume of sand wet and compacted (including pore space), whence
(Vt − Vs) = volume of water above compacted sand, and
Vw − (Vt − Vs) = water in the pores of the sand (the total water less the water above the sand), or
Vw − (Vt − Vs) = actual porosity in the wet packed sand, whence

$$\frac{Vw-(Vt-Vs)}{Vs} = \text{proportion of porosity in wet packed sand.}$$

To get the porosity in the dry loose sand, use the following formula, having first measured the volume of the sand, dry and unpacked:

$$\text{Voids} = \frac{Vw-(Vt-Vd)}{Vd.}, \text{ in which}$$

Vd = the volume of the dry sand, all the other symbols being the same as in the previous formula.

The chief objection to the use of this method lies in the fact that by pouring the sand into the water there is a slight tendency to stratification, the finer particles forming layers at the top. In this manner, any given layer of sand becomes more uniform in size of grain than it was before, with a consequent tendency toward increased pore space. The fine grains, which would normally fill the openings between the larger ones, are massed at the top. This stratification will sometimes give a slightly excessive figure for voids by this method. Just how important this error might become is suggested by the following facts: (1) In a well-rounded sand absolutely uniform in grain, the maximum porosity is 47.64 per cent and the minimum 25.95 per cent. These extremes are practically never reached, the average being about 44 per cent.[1] (2) By careful grading and proportioning, mixtures can be produced with porosity as low as 10 per cent or 15 per cent, though this figure is of course much lower than the average for graded aggregates.

[1]Taylor, F. W., and Thompson, S. E., Concrete, plain and reinforced, 2d. ed., p. 169, 1911.

It is thus seen that by stratifying the sand, its uniformity in any given portion of the mass tends to be increased, with consequent increase in the porosity. To reduce the error to a minimum, care should be taken to see that the sample is thoroughly mixed on a sampling cloth before pouring. The sand should then be allowed to fall as short a distance as possible through the water. With a reasonable degree of caution, the error should not be large.

A variation of this method is to pour the water into the sand instead of the sand into the water. This eliminates stratification, but introduces an error in the opposite direction which is undoubtedly even more serious. In pouring the water into the sand, it is very difficult to get the pores completely filled, as many of them still retain air bubbles. In tests with this method, the mixture of sand and water after standing five hours still showed large bubbles which could not be shaken out. This incomplete filling of the pores with water results in a porosity lower than should properly be obtained, and will not give as uniform results as by pouring the sand into the water. Tests on a very coarse sand by both methods showed only a slight discrepancy, the latter method giving a pore space 2 per cent lower than the former. On fine sand, however, the difficulty is increased, because the water penetrates with more difficulty. On a moderately fine-grained sand, the former method gave rather consistent results, three trials of the same sand varying by less than 2 per cent; by the latter method (pouring the water into the sand) three trials varied from one another by over 4 per cent, and ran from 3 per cent to 6 per cent lower than when the sand was poured into the water.

Another method, based on the same principles as the one above, is to bubble the water up through the sand from below. The apparatus for this consists of a box or dish to hold a known quantity of sand. To an opening in the bottom attach a rubber tube and connect this with a graduated glass tube containing water. The graduate must stand sufficiently above the sand box to force the water down through the rubber tube into the sand. The flow of water is controlled by a pinchcock on the hose. A fine screen over the opening in the sand box prevents the sand from passing out into the tube below. After the graduated glass tube has been filled with water, the cock is opened, and the water allowed to rise in the connecting tube just even with the bottom of the empty sand box in order that

it will not be necessary to compute the water in the connecting tube. The sand box is now filled with sand, and "stricken off" with a straight edge. If it is the porosity in loose dry sand that is desired, the sand is sifted into the box from a given height. If it is the voids in wet packed sand that is desired, the box is filled and tamped by a uniform method. In either case the water in the graduate is read. The pinchcock is then opened, and the water allowed to run till it just begins to overflow the edge of the box. The cock is then closed, and the water in the graduate again read. The difference in the two readings is the water let into the pores of the sand. In other words, it is the actual volume of the voids. Expressed in formula this becomes,

$$\text{Voids} = \frac{Vw}{Vb}, \text{ in which}$$

Vw = volume of water introduced
Vb = volume of the box.

Even by this method there are likely to be air bubbles left in the sand. In order to detect these, glass containers of various shapes and sizes were used, and it was found that a container not too deep and high and an inflow of water fast enough to stir the sand slightly seemed to eliminate the bubbles best. It was found impossible, however, to expel the air entirely. This method, because of the air bubbles, gives a figure somewhat too small, just as the fact that sand stratifies when poured into the water, is likely to give a value too large. It is the method most commonly used in laboratories.

Numerous tests of voids on large and small samples of the same sand showed, as might be expected, that results on large samples were more consistent. With small samples (less than 100 cc.) successive tests on the same sample showed variations of from 2 to 5 per cent, while on larger samples (300 cc. or more) repeated trials checked to from ½ to 2 per cent. Small samples seemed to show a higher porosity, due probably to less compacting by weight of the sand itself.

Still another and probably the most accurate method of determining voids in a sand is the specific-gravity-weight method. First determine the specific gravity in the manner already indicated. Suppose this to be 2.64. Measure out in cubic centimeters a given volume of sand, say 100 cc. Then, if there were no voids, the sand should weigh 264 grams. (The weight of 1 cc. of water is 1 gram, and sand weight 2.64 times as much.)

Weigh the sand. Because of the voids, it will weigh less. Suppose it weighs 144 grams. The difference in weight caused by the voids is 120 grams, that is, 120 grams of sand will fill the voids. Then

$120 \div 2.64 =$ volume of voids in cc.
$(120 \div 2.64) \div 100 = .454$ or 45.4 per cent voids.

Expressed as a formula his would be:

$$\text{Voids} = \left\{ \frac{\frac{(Vc \times G) - W}{G}}{Vc} \right., \text{ where}$$

Vc = volume in cc.
G = specific gravity
W = weight in grams.

If the measurement is made in cubic feet, the formula will be:

$$\text{Voids} = \left\{ \frac{\frac{Vf \times 62.5 \times G - Wlb.}{G \times 62.5}}{Vf} \right., \text{ in which}$$

Vf = volume in cubic feet.
G = specific gravity
Wlb = weight in pounds.
$62\frac{1}{2}$ = weight in pounds of one cu. ft. of water.

For the sake of convenience, one cubic foot is usually taken. Then 62.5 lb., the weight of a cubic foot of water, times 2.64, the specific gravity of the sand is 165 lb., the weight of a cubic foot of the sand, if there were no pores. If the actual weight were 100 lbs., then 65 lb. the deficit, is the weight of the sand which would fill the pores. Then the proportionate volume of the pores is $\frac{65}{2.64 \times 62.5}$..394, and the percentage voids is 39.4. It will at once be noted that as the volumes are in proportion to the weights, the percentage voids can be determined by dividing the difference in weight directly by the theoretical solid weight. In the first instance 120 is divided by 264 and in the latter 65 by 165.

A knowledge of the voids in a sand or a gravel is of considerable value, because in aggregates for concrete, the lower the voids, the less cement is required for mixing. A well-graded and proportioned aggregate containing several sizes from coarse to fine is more economical than a very uniform aggregate with a high porosity, because a low uniformity coefficient signifies, in a general way, high voids, while a high coefficient is associated with lower voids. Under detailed descrip-

tions by formations and districts, will be given the voids of those sands on which tests were made. On the tested sands, voids ranged between 27.8 per cent and 58.8 per cent.

WEIGHT OF SAND.

The weight of sand depends directly on two factors, the specific gravity and the percentage voids; and the voids, as has been noted, are in turn dependent on degree of grading and compactness. In the following discussion, unless otherwise stated, it is assumed that the sand is dry. In ordinary practice, the weight is expressed in pounds per cubic foot or per cubic yard. Among sand users, the common method to find the weight of sand is to fill and weigh a box holding exactly one cubic foot. The weight of the sand may be expressed, either loose or compacted. If loose, the sand should always be poured into the box from a standard height. If compacted, it should be done by means of a uniform amount of shaking, or by a uniform weight placed on the sand.

Where only small samples are to be had, a common laboratory method is to find carefully the weight in grams of a sample of about 100 cc. of the sand. This can be reduced to pounds per cubic foot by the following formula:

Wpf. = Wgc × 62.513, in which
Wpf. = weight per cu. ft. in pounds,
Wgc. = weight per cc. in grams.

This is derived as follows:

1 cc. $= \frac{5}{82}$ cu. in.

1 g m. $= \frac{75}{34000}$ lb., then let

X = weight of 1 cc. in grams, then

X = weight of $\frac{5}{82}$ cubic inches in grams.

Weight of 1 cu. in. $= \frac{82\ X}{5}$ grams.

1 cu. ft. = 1728 c. in.

Weight of 1 cu. ft. in grams $= \frac{1728 \times 82\ X}{5}$

Weight of 1 cu. ft. in pounds $= 1728 \times \frac{82\ X}{5} \times \frac{75}{34000} = 62.513\ X.$

Where specific gravity and voids are already known, the following computation may be used:

$$\text{Weight per cu. ft.} = G \times 62\tfrac{1}{2} \times \left\{ \frac{100 - v}{100} \right\}, \text{ in which}$$

G = specific gravity,
V = per cent voids, and
$62\frac{1}{2}$ = weight in pounds of one cu. ft. of water, whence
$G \times 62\frac{1}{2}$ = weight of one cu. ft. of sand if perfectly solid, then
$\frac{100 - v}{100}$ = proportion of actual sand without voids.

This method was used in making the computations for this report.

Under detailed description of sands by formations and districts will be given the weights of the various sands tested. They were found to range between 67.72 and 118.7 lb. per cubic foot, or between 1828 and 3205 lb. per yard. All figures given in this report are for sands dry and unpacked. It is interesting in this connection to note that

"The mixture of a small amount of water with dry sand increases its bulk. In the case of most bank sands the maximum volume—and hence the smallest amount of solid matter per unit of volume, that is, the largest percentage of absolute voids—being reached with from 5% to 8% of water." [1]

This is due to the fact that a fine film of water separates the individual grains, actually holding them apart. This is not noticeable in aggregates of one-half inch and above, but its importance increases with the finer sands. As a result, slight moisture actually causes the sand to weigh less. The same writers also say:

"It is noticeable that both the loose and tamped sand increase in volume with the addition of water and reach a maximum with about 6% of water, then decrease, and finally, when saturated, return to slightly less than their original dry bulk." [2]

Though a damp sand may be slightly lighter than the theoretical dry weights computed by the method given above, it is to be remembered that actual shipping weights will frequently exceed the figures given, because as most sands and gravels are shipped directly from the washer or dredge, they are practically saturated, as is plainly shown by the water running from newly loaded cars. With a porosity of 30 per cent, which is below the average for river sands in this state, a com-

[1] Taylor, F. W., and Thompson, S. E., Concrete, plain and reinforced, 2d ed., p. 161 1911.

[2] Op. cit., p. 177.

plete saturation of the pores with water would raise a sand weighing 116 lb. per cubic foot dry to about 136 lb. per cubic foot saturated, or from 3132 lb. to 3672 lb. per cubic yard.

CHEMICAL COMPOSITION.

For most uses to which sand is put, a knowledge of chemical composition is of little or no value. Analyses were made of such sands as were of probable or possible value in glass manufacture, or for moulding sands. As a matter of scientific interest, one analysis each was made of Missouri, Mississippi, and Meramec sands. The oxides determined were SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, and volatile matter.

In the glass sands the silica is present chiefly as the mineral quartz (SiO_2) and probably a very small amount combined with the alumina (Al_2O_3) in the mineral Kaolinite, ($Al_2O_3.2SiO_2.2H_2O$) or related hydrous silicates of weathering, since few or no unweathered primary silicate minerals are to be detected in the glass sand formations. The Fe_2O_3 is present largely as limonite ($2Fe_2O_3.3H_2O$) or other related hydrous oxides, in the form of an extremely thin coating on the individual grains, more rarely as a cement actually filling the pores. This latter condition is usually found where there is a heavily ferruginous crust, caused by an excessive leaching of iron from the soils or rocks above. The CaO and MgO are probably present as the carbonates, calcite and dolomite, as cementing material.

Computing Al_2O_3 as kaolinite, Fe_2O_3 as limonite, and the CaO and MgO as carbonates, it will be found that the H_2O and CO_2 required totals practically as much as the actually determined volatile constituents, showing that there is but little organic matter present. In a few instances there is not enough actually determined volatile matter to furnish the computed amount of CO_2 and H_2O, which may mean that Fe_2O_3 is present as göthite ($Fe_2O_3.H_2O$), turgite ($2Fe_2O_3.H_2O$), or even as hematite, (Fe_2O_3). This would reduce the computed amount of water. In some cases this would still leave a small deficiency which possibly signifies that a very small amount of the alumina, lime, and magnesia may yet remain as unweathered silicates. It might also signify the presence of some weathering product of Al_2O_3 lower in water than kaolinite.

Feldspar, if present might add potash, soda, lime, and alumina; and the ferro-magnesian minerals would yield in addition further amounts of iron and magnesia. These minerals

are not present in appreciable quantities in the glass sand formation.

In a general way it may be said that chemical analyses yield the following information that is of value for any given sand. For glass making it is desirable to know the content of silica, iron, alumina, magnesia, and organic matter (See pp 80-84). For moulding sands, especially for steel moulding, the content of silica, alumina, iron, magnesia, lime, and alkalies should be known (See pp 73-77). For fire and furnace sands, the percentage of silica, iron, lime, magnesia and alkalies should be determined (See p 85). For filter sands the percentage of silica, iron, lime, magnesia, alkalies and organic matter should be determined (See pp 78-80). For concrete work, it may become desirable to determine the organic matter (See p 57). According to the Bureau of Standards,[1] there are often made for a building sand

"Chemical determinations of the presence of organic matter, sulphides, soluble alkalies, etc. The chemical tests need not be made unless the material is found to be inferior in quality, and the cause cannot be determined by physical tests."

REFRACTORINESS.

Refractoriness is that property which enables a sand to undergo high temperatures without fusing. Pure quartz is in itself a very refractory substance, and consequently, a quartz sand of high purity is fusible only at very high temperatures. Lime, iron, magnesia, and the alkalies act as fluxes and the sands in which these impurities run high are much more easily fusible. The presence of calcite, limonite, and many of the silicate minerals carrying lime, iron, or alkalies, fluxes the sand and reduces its refractoriness.

It is the fusing point of sands that determines their value, especially for furnace and foundry purposes. Practice has shown that the St. Peter sand is sufficiently refractory to be suitable for furnace lining and core sand, and for these purposes it is largely used. No laboratory experiments have been carried on with respect to the refractoriness of Missouri sands.

[1]Circular No. 45, p. 36, 1913.

CHAPTER II.

METHODS OF PRODUCTION AND MARKET CONDITIONS.

METHODS OF LOADING SAND.

Throughout the State, there are many sand producers who handle their product wholly, or in large part, by hand. This is true of sand and gravel used for structural purposes, and to a slight extent even of St. Peter sand for glass manufacture and foundry work.

LOADING BY HAND INTO WAGONS.

Creek sand and gravel, and bank sand and gravel are secured at many points by loading by hand and hauling by teams. In those regions where sand and gravel are abundant, where every little stream has its sand and gravel bars, as in the Ozarks, there are few regular dealers handling these products strictly for home consumption. When such material is desired, it is simply a matter of driving to a creek and shoveling it into the wagon. In most places no charge is made except for haulage. Farmers do their own hauling, and contractors hire a drayman or other teamster. Along the Missouri, and to a lesser extent along the Mississippi, bar-sand is secured in the same way when the water is sufficiently low. At St. Charles and at Lexington, regular sand dealers secure their sand supply in this way, piling it up as stock from which to supply the trade during periods of high water.

In places where the sand supply is not so general, good pits or bars are controlled by owners or renters who either haul the sand to the consumers, charging both for haulage and sand, or who keep the pit in shape, charging a varying amount per yard to each person who gets sand. This charge varies up to as high as one dollar where there is a heavy overburden which the owner must keep stripped back. Pits of this sort are kept open by the owners at Commerce and Benton in Scott County, at Dexter in Stoddard County, at Campbell in Dunklin County, and at

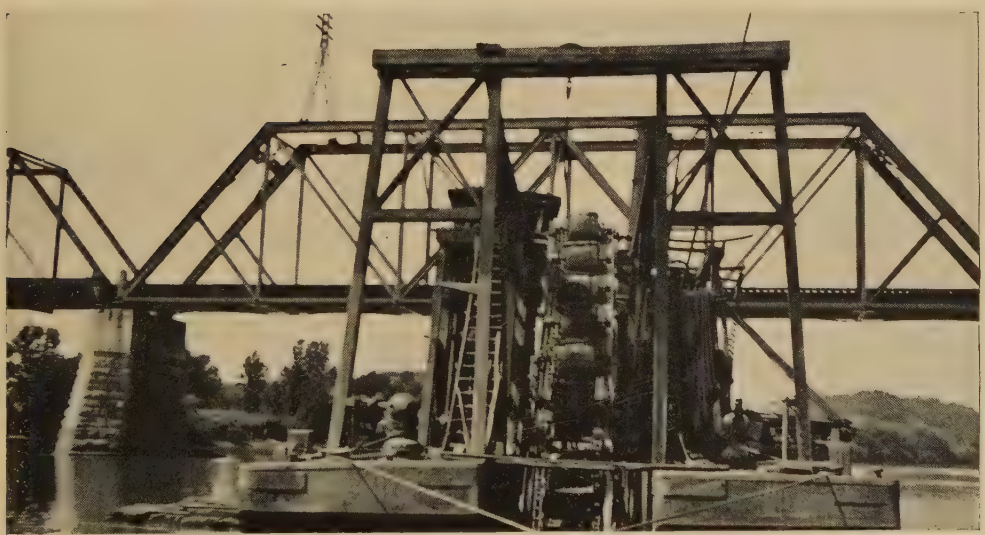
various points in Nodaway County, especially at Maryville and Guilford.

In some places, sand for shipment is loaded by hand into wagons and hauled to the railroad. Where this is done, there are two methods of loading the sand into the cars. First, by shoveling it from wagon to car, as at Steelville where foundry-bed sand is procured for shipment to the Sligo Furnace, and at one of the St. Peter quarries at Pacific; second, by unloading it from the wagon into the cars by means of what is known as a trap. For this method, a bridge-like structure (Pl. I, A) is built over the railroad siding. The car stands under this structure, in the floor of which there is an opening. The loaded wagon is driven up an incline onto the trap, straddling the opening and is dumped by means of the ordinary dump boards, the load falling into the car below. This method has been used by contractors on the Missouri Pacific Railway, loading ballast at Mill Spring on Black River in Wayne County; by Rock Island ballast contractors at various points in Osage County on creeks tributary to Osage River; and in the pit of the Pacific Cement Gravel Company at Pacific. In haulage by wagon the size of the load varies from one to two yards, depending on the character of the roads and the length of the haul.

LOADING BY HAND ONTO BARGES.

At Boonville there are sand dealers who handle their sand by hand but who operate on a somewhat different basis. When the water in the Missouri is sufficiently low to expose the sand, barges are towed by gasoline or steam tug to the bar. The barges are loaded by hand, sometimes by shoveling the sand directly onto the boat, at other times by using wheelbarrows. The loaded barges are towed to the city where the sand is shovelled by hand into wagons to be delivered directly to the trade, or is unloaded by means of wheelbarrows, onto stock piles, for future delivery. A plant at Poplar Bluff on Black River uses the same method. It is said that from 3 to 6 yards per man per day is about the capacity by this method, depending on the distance the sand has to be towed.

A. Gravel pit of Pacific Cement Gravel Company, near Pacific, in Franklin County. Lafayette (?) gravel. Shows two typical loading traps.



B. Osage River Gravel Company, Osage City. Bucket dredge operating on Osage River, Cole County.

LOADING BY HAND INTO CARS.

At several of the glass sand plants, the sand after being blasted down is loaded by hand onto cable tram cars and hauled to the crusher. Trams are not used in this State in the production of bar or bank sand.

At no point in this State is it known that sand is loaded by hand directly into railroad cars, though this method is in vogue at many ballast pits in other States.

LOADING BY HAND WITH SAND DIPPERS.

At Maitland on Nodaway River, a unique method of handling sand is practiced by several local sand dealers. Small flat boats propelled by poles are provided with sand boxes holding about ¼ to ½ yard of sand. Each boatman is furnished with a long pole on the end of which is a dipper shaped very much like a large funnel. With this the man dips up the sand from the bottom of the stream and fills his sand boxes. The boat is then pushed to the landing, where the boxes are hoisted to the stock pile by horse and derrick, or drawn up an inclined track. From the stock piles the sand is loaded by hand into wagons and hauled to the point of consumption. It is reported that a man can dip from six to eight yards per day.

LOADING WITH SCRAPER AND TRAP.

At a few places, sand or gravel is loaded directly into the car by means of a scraper which operates over a trap similar to the one described in a previous section. Over the railroad track is a bridge with a hole for dumping the sand. The car stands under the opening. Both hand and wheel scrapers are used, the scraper being dumped over the opening. This method is employed for getting out road gravel at Pacific (Pl. I, A), and for loading ballast at Mill Spring in Wayne County. There was so much difficulty, however, at Pacific in getting horses that would work over the trap, that a donkey engine was installed, the scrapers being operated largely by drum and cable.

LOADING WITH STEAM SHOVEL.

At the St. Louis and San Francisco ballast pit near Wittenberg in Perry County, the gravel is loaded directly into the car by means of a steam shovel. The steam shovel is also employed in loading glass sand into the quarry cars in the quarry of the Enterprise Sand and Mining Company, just south of Herculaneum in Jefferson County (Pl. II, A), and in the quarry of the Tavern Rock Sand Company, at Klondike in St. Charles County.

LOADING WITH CLAM SHELL DREDGE.

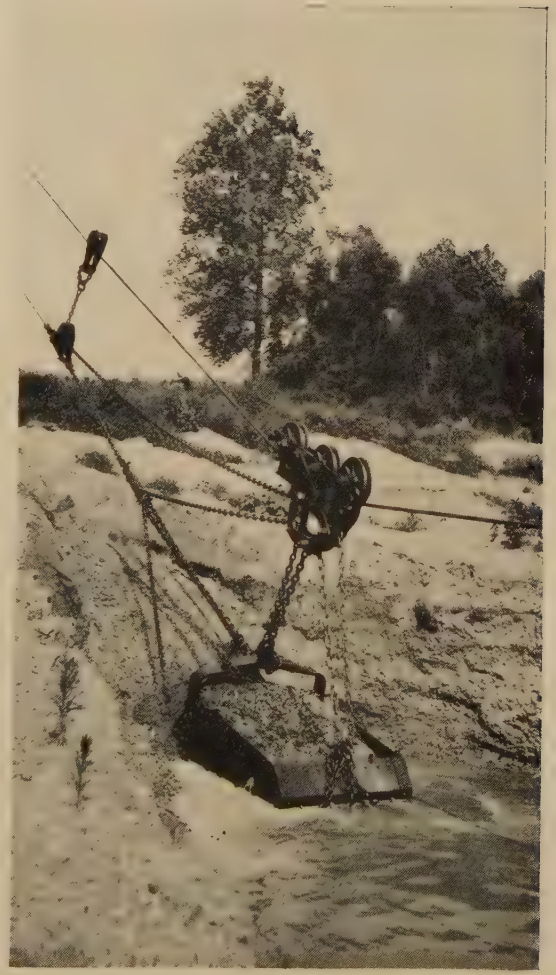
The clam shell dredge (Plate VI), which is used so extensively in Nebraska to deliver the sand directly from the bar to the cars, has not found such universal favor among the sand producers of Missouri. It is used extensively for unloading sand from the barge to the car at many sand pumping plants, but at only one point was a clam in operation delivering the sand from the sand bar directly into the car, as is done so extensively along the Platte in Nebraska. At Mill Spring, Wayne County, ballast has been loaded in this manner, though the plant was temporarily closed down and the clam shell removed when the plant was visited by the writer in June, 1914.

LOADING WITH CABLE DRAG-LINE.

Somewhat similar to the clam shell, is the cable drag-line (Plates II, B; III, A; and III, B). A tall mast is firmly anchored beside a spur of the railroad at the edge of a good sand or gravel bar. A steel cable extending from the top of the mast out over the gravel bar is anchored to a buried log, or "dead man." On this cable runs a pulley which carries a bucket shaped like a huge scoop shovel, open in front. The bucket runs by gravity over the bar down the inclined cable track. The release of the lifting cable drops the bucket to the bar at any desired point along the track. To the front of the bucket is attached a drag cable which drags the scoop forward till it is filled. It is then raised by means of the lifting cable and drawn along the track till it is above the car, where it automatically dumps. The bucket can be made to dump on a stock pile, in the car, or in the hopper of a screening tower. Plants of this character operate

A. Quarry of Enterprise Sand and Mining Company, Herculaneum, Jefferson County. St. Peter sandstone. Shows steam shovel loading quarry cars.

B. G. W. Camery's plant on Salt River, near Hannibal, in Ralls County. Shows cable drag line in operation.



G. W. Camery's plant, on Salt River, near Hannibal, in Ralls County. Shows cable drag line in operation.

on Salt River in Ralls County, at Pacific on Meramec River, and at Arlington on Gasconade River in Phelps County. About 600 feet is the maximum length of cable over which a bucket can be operated successfully.

LOADING WITH BELT-BUCKET DREDGES.

At Osage City on Osage River, there is being operated the only bucket dredge in the State for handling sand (Plates I, B and IV, A). On a large barge is arranged an endless belt with attached buckets which can be lowered at one end until the moving belt and buckets come in contact with the gravel on the river bottom. The gravel travels up the belt, passes through screens, is loaded onto a second barge and towed to shore. This type of dredge can be operated only in comparatively shallow water.

LOADING WITH CENTRIFUGAL PUMPS.

In the State are a great many plants at which river sand and gravel are pumped. Some of these are seen on Mississippi River, Missouri River, Black River, Joachim Creek, Meramec River, Gasconade River, and Nodaway River. The pumps vary from 4 inches to 15 inches in interior diameter, and under average conditions of pumping, are reported to range in capacity from about 40 yards to 250 yards per hour.

Numerous difficulties are met in the pumping of sand. One of the greatest is the frequent clogging of the intake with roots and driftwood, which necessitates the slowing down of the speed until the suction is sufficiently reduced to allow the rubbish to drop off the coarse screen over the intake. Sometimes it becomes necessary to raise the intake above the water and pick the roots and fibres out of the screen. This difficulty is most pronounced in small streams, but is scarcely met with by the plants operating on the Mississippi and the Missouri.

Another difficulty is the cutting out by coarse gravel of the expensive manganese steel linings of the pumps. The more powerful pumps have to be relined once in every four to six weeks, but the less powerful, because they handle a finer product, are not cut out so rapidly.

Still another difficulty is the inability of the operator to procure sand of the desired size of grain. River bars shift so rapidly, especially where the bottom is disturbed by the pumping operation, that where good coarse sand is being secured one

day, fine quicksand, quite undesirable as a commercial product, is found the next day. This necessitates sounding with a long iron pipe. An expert sounder can judge the size of grain by the compactness of the bar, as shown in its resistance to penetration by the iron pipe. A frequent moving of the pump is necessary, especially on the Missouri.

Gravel up to a diameter of from 3 to 6 inches can be handled by the larger pumps, but it is customary to protect the intake with crossed bars which keep out all material coarser than the largest grade desired in the commercial product.

Pumping can be carried on in water which varies in depth from 1 or 2 up to 20 or 30 feet. About 5 or 6 feet, however, is most convenient, as this depth is sufficient for the floating of the barges and is yet shallow enough not to demand excessive suction.

One of the advantages of the pump over other types of dredge is the fact that the sand is thoroughly washed through the pump, a considerable quantity of fine sand and silt being carried out by the overflow from the barges.

The greater part of the pumped sand is delivered by the pumps to barges which are towed by steam or gasoline tugs to the landings (Plate V, B). In a few instances the barges are merely floated down river, and the full boat returned by drum and cable.

At a few places, the pump delivers the sand directly to the shore. At Crystal City, the Universal Company formerly operated a pump on a barge anchored at the foot of a bar near shore, which delivered the sand through a pipe directly to the hopper of the washing and grading plant. At Silica, Harrison Brothers (Pl. IV, B) have a pump on Joachim Creek, which delivers gravel through a pipe to a bucket elevator, which in turn delivers the gravel to the cars. Formerly, the pump delivered directly into the cars, but it was found that the overflow tended to undermine the tracks to such an extent that a bucket elevator was introduced, together with a flume to carry away the overflow.

At Canton on Mississippi River, the pump delivers to a stock pile on shore through a 400 foot pontoon pipe line which has to be swung around next to shore for the passage of river steamers (Pl. V, A). To prevent loss the overflow runs over a board riffle which settles out most of the sand. At this plant it is planned to build a loading hopper into which the pump will deliver and which in turn will deliver by gravity to the cars.

A. Osage River Gravel Company, Osage City, in Cole County. Detail of dredge buckets.

B. Harrison Brothers' dredge, on Joachim Creek, near Silica, Jefferson County.

A. Canton Fuel Company's plant, at Canton, Lewis County, on Mississippi River. Shows pontoon pipe line from dredge to shore.

B. Meramec Portland Cement and Materials Company's plant, at Sherman, St. Louis County, on Meramec River. Shows sand and gravel discharging from fifteen-inch centrifugal pump onto barge.

UNLOADING FROM THE BARGE.

Most of the large producers pump the sand onto barges and then tow these for distances varying from a few rods to 6 or 8 miles. Several methods are used for removing the sand from the barges.

UNLOADING BY CLAM-SHELL.

By far the most common method of unloading barges is by use of clam-shell buckets, similar in general principles to clam-shell and orange-peel buckets used so extensively in handling coal. They vary considerably in detail, but typical examples may be seen in Plate VI. In its essential parts, a bucket consists of two halves resembling the two parts of a large clam shell. At the top these are hinged to a heavy steel bar, and are so mounted that when hanging free the shells are open. The weight of the shell is so great that it sinks readily into the sand or gravel, and the lifting cables are so applied that the first strain causes them to close the clam before it is lifted. The clams vary in capacity from 1 to 5 yards.

While all clams are essentially alike in operation, the method of handling them varies widely. At some plants, the clam is operated by a mast and swinging crane (Plate VII, A) in such way that the sand can be dumped either directly into the cars, or onto a stock pile from which it can be reloaded by the shell into the cars. Plants of this type operate at St. Joseph, Glasgow, Boonville, and Jefferson City, on Missouri River. At other places, the clam, suspended from a pulley carrier, travels on a steel track, precisely as does a common hay-fork (Pl. VII, B). The Union Sand and Material Company's plant at Hannibal is of this latter type, and the clam delivers directly to the screening tower.

The sand may be delivered directly from barge to car or to stock pile. If the latter, the pile is so placed that the clam can again deliver from the pile to the car. In this type, the railroad track usually passes between the tower and the stock pile, the carrier track being long enough to reach across the railroad spur from barge to pile. At the Stewart-Peck plant in Kansas City, the tower supporting the carrier track and clam runs on wheels on a track parallel to the river. By this means, the whole tower can be shifted, giving a much larger area for stock piling within reach of the clam (Pl. VIII, A).

At other plants, especially where the sand or gravel is screened and washed, the clam delivers to a hopper which drops the sand slowly onto an endless belt conveyor (Pl. VIII, B). This in turn delivers it either to the loading hopper or to the screening tower. Belt elevators are used in connection with the clam at the St. Louis plants on the Mississippi, and at the plants at Sherman, Drake, and Valley Park on Meramec River.

UNLOADING BY BOX HOIST.

The plant at Osage City has a mast and swinging crane to which is attached a box with a capacity of one yard (Pl. IX, A). This box after being filled from the barge by shoveling, is hoisted with a donkey engine. The mast is so inclined that while the box is being hoisted, the crane swings by gravity out over the car, into which the box is dumped by a man who cuts out one of the handle chains, allowing the box to upset. A hoist similar to this is operated by horse power at Maitland.

UNLOADING BY CAR AND TRACK.

The Buchanan Sand and Supply Company's plant at St. Joseph is equipped with an inclined track and with an electric car (Pl. IX, B). The lower part of the track is operated like a draw bridge. After the track is lowered in place, the car is let down on the barge by gravity, filled by hand, hauled up the incline by electricity, and is automatically dumped on a stock pile. The Morrison Ice and Fuel Company at Cape Girardeau also unloads from the barge by automatic dump cable cars.

UNLOADING BY BELT ELEVATOR.

Plants at Poplar Bluff and Louisiana use an endless belt conveyor which operates directly from the barge either to a loading hopper or to a stock pile. The sand is shovelled by hand from the barges onto the belt

UNLOADING BY HAND.

At a few places, as has already been said, barges are unloaded by hand either into wagons directly, or onto a stock pile.

A. Clam shell, Missouri River Sand and Gravel Company, at Boonville, Cooper County.

B. Clam shell in operation. Union Sand and Materials Company, St. Louis, on Mississippi River.

A. Plant of Pioneer Sand Company, St. Joseph, Buchanan County, on Missouri River. Shows clam shell handled by mast and swinging crane.

B. Plant of Union Sand and Materials Company, St. Louis, on Mississippi River. Shows track and traveling clam shell.

LENGTH OF SAND DREDGING SEASON.

The sand dredging season is variously reported as from eight to twelve months, the shorter period obtaining in the northern portion of the state. Even in that section, there are years when pumps can be operated continuously. The greatest hindrance to the trade is the fact that during the coldest weather the wet sand freezes in the cars, making it difficult to unload. For that reason, little shipping of wet sand is done during the winter months.

SAND QUARRYING.

The St. Peter sandstone, the only consolidated formation in the State from which there is any considerable production at the present time, does not lend itself to the methods of handling which have been outlined in the foregoing descriptions. It is nearly always necessary to blast down the rock. The quarrying is done both by open pit and by underground methods.

In the open pit quarries (Pl. X, A) there is usually an overburden consisting either of loess or of limestone or often of both, which varies from a few inches to 30 feet or more in thickness. When the covering is of limestone, shooting is invariably a part of the stripping operation. In a few of the open pit quarries the overburden is simply blasted down over the face into the bottom of the quarry, but in other places it is removed by team and scraper. At the Klondike quarry it is removed by an aerial gravity tram. Even the loess overburden is usually so compacted that it must be blasted or at least plowed before removing it. Frequently it is taken away by team and scraper. At one of the quarries just east of Pacific, the loess is blasted loose and removed by hydraulic means. In most of the St. Peter quarries, the sand is sufficiently cemented to make blasting necessary. Drilling is usually done by steam or compressed air drills, though in a few of the smaller quarries hand drilling is the rule. The sand is then shot down into great piles either of broken blocks or loose sand, depending on the degree of cementation. At most of the quarries, the sand is loaded into the quarry cars by hand. The Enterprise Sand and Mining Company uses a steam shovel, as does also the Tavern Rock Sand Company.

Haulage is done by mules, drum end cable, gravity, or electric locomotive.

SPINDLETOP ENGINEERING LIBRARY
LAMAR STATE COLLEGE OF TECHNOLOGY

At a few places, where the overburden is particularly heavy, underground methods of quarrying have become necessary. The Pittsburgh Plate Glass Company at Crystal City operates at present exclusively in tunnels (Pl. X, B). The Silica White Sand Company at Silica, the Pacific Glass Sand Company at Pacific, and one of the Tavern Rock Sand Company's quarries at Pacific, are operating partly by open pit and partly by tunnel methods.

PREPARATION OF SAND FOR THE MARKET.

Not much of the sand in this State undergoes special preparation before being put on the market. However, certain special sands and sands for certain special uses go through one or more of the processes of crushing, washing, screening, or drying.

CRUSHING SAND.

Although an unusually friable sandstone, the St. Peter generally requires crushing before it is fit for use. At a few places, the rock is so soft that the simple washing through a coarse rotary screen is sufficient to cause it to crumble to a fine sand. In most places, however, regular crushers are employed, the most popular types being the Allis-Chalmers Gyratory Crusher and the Williams Hammer-Mill.

Aside from the St. Peter sandstone, the only natural sand or gravel product in the State to be crushed is near Sedalia where a rather coarse flint creek gravel is run through an ordinary rock crusher before being put on the market.

WASHING SAND.

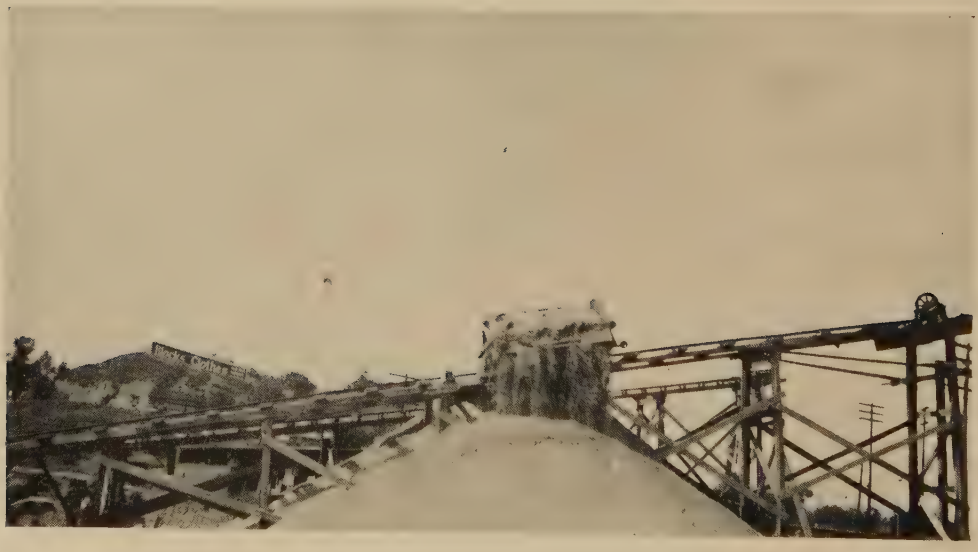
The greater number of those plants producing sand for structural purposes, put their product on the market unwashed, or with only such washing as is secured by passing the sand through a centrifugal pump.

The plant managed by Mr. H. B. Straight, at Crystal City (Pl. XI, B), had a secret process of washing and grading sands for filter purposes. A few other plants, as those at Silica, Crystal City, Drake, Sherman, Valley Park, Hannibal, and Osage City wash the sand and gravel to be used in structural work. Usually this is accomplished by carrying a two to four-inch stream of water to the top of the screening tower (Pl. XI, A), where it is directed into the sand as it passes over the inclined

A. Plant of Stewart Peck Sand Company, Kansas City, on Missouri River. Clam shell handled by traveling crane.

B. Plant of Continental Portland Cement Company, Valley Park, St. Louis County, on Meramec River. Shows sand conveyed from clam shell to screening tower on endless belt conveyor.

A. Box hoist, Osage River Gravel Company, Osage River, Cole County.



B. Plant of the Buchanan Sand Company, St. Joseph, Buchanan County, on Missouri River. Car and track for unloading sand from barge.

screens. The purpose of washing is to get out the mud and silt and to facilitate the separation in screening.

Such washing is particularly to be commended where the surface of the pebbles of a gravel or the coarser grains of a sand are coated with mud or other impurity, which may form a film that would prevent the proper adhesion of the cement or lime to the grains. The desirability of washing simply to get rid of small quantities of clay may be questioned, in view of the evidence already presented (pp. 10-11.) that a little clay, except in the presence of sea water, does not unfavorably affect the strength of a mortar.

To users and producers of Missouri River sand, which is frequently highly lignitic, the following process of washing used on Allegheny River sands may prove of value.[1]

"The sand contained earthy matter and some coal, the latter being hard to remove by ordinary processes. A large barrel or tank nine feet in diameter and seven feet high, was provided with double floor, the upper one being pierced with one-inch holes. Paddles were attached to a vertical shaft in the axis of the tank and revolved by suitable gearing, while water was forced into the space between the two floors. The water finding its way through the holes in the upper floor, passed up through the sand and overflowed at the top, carrying with it the coal and the sediment. The cost of washing is said to have been about seven cents per cubic yard, but it is evident that methods of handling would have to be quite perfect, to keep the cost at so low a figure."

Only two plants operating in the State wash their glass sand, the others shipping their sand unwashed. The washing process consists in passing a mixture of sand and water over riffles, or through successive settling tanks, where the coarse material settles, and the finely divided iron and alumina and much undesirable fine silica are floated off on the water. This waste is utilized in the material used for grinding-sand. The washing usually gives an appreciable reduction in Fe_2O_3 (oxide of iron) and Al_2O_3 (alumina).

Below are given comparative analyses of washed and unwashed glass sands. The figures represent the average of a large number of analyses and were furnished by Mr. F. Gelsthorp, Chief Chemist of the Pittsburgh Plate Glass Company. The sand is from Crystal City.

---

[1]Sabin, L. C., Cement and Concrete, 2d ed., pp. 183-184, 1907.

Comparative analysis of washed and unwashed St. Peter sand.

	Quarry run sand.	Washed melting sand.
Loss on ignition	0.170	0.100
Oxide of iron	0.075	0.031
Al_2O_3	0.210	0.049
CaO	0.072	0.020
MgO	0.068	0.018
SiO_2	99.405	99.782
	100.000	100.000

The following is an analysis of a slime from the washing of St. Peter sand at Ottawa, Illinois.[1]

Analysis of slime from washing of glass sand.

SiO_2	87.21
Al_2O_3	7.50
Fe_2O_3	.52
CaO	.00
MgO	.....
Alkalies	.20
Remainder chiefly H_2O.	
	95.43

From this analysis, it may be seen that washing appreciably lowers the alumina content of sands. The following extract from a letter from Mr. F. Geisthorp, Chief Chemist of the Pittsburgh Plate Glass Company, is of decided interest in this connection:

"Regarding the clay, this is usually removed from sands intended for glass melting by washing, which also usually reduces the iron content. Therefore, before a proper opinion can be passed regarding the suitability of a sand for glass melting purposes, the analysis should be made of the material after it has been washed free from clay, etc. Apparently worthless sands are sometimes lowered in this way so much in iron as to pass into a class very suitable for glass melting."

SCREENING SAND.

Most of the plants pumping sand or gravel from Missouri streams use a screen either over the intake or below the discharge of the pump, to keep out gravel coarser than that desired in the commercial product. By this method, the undesirable material is returned directly to the stream bed. Besides this screening, some plants are equipped with the apparatus

[1]Burchard, E. F., Mineral Resources of U. S. for 1911, pt. II, p. 597.

A. Open pit quarry in St. Peter sandstone. Silica White Sand Company, Silica, Jefferson County.

B. Quarrying St. Peter sandstone in tunnels, by mining methods. Pittsburgh Plate Glass Company, Crystal City, Jefferson County.

A. Screening and washing tower; plant of Meramec Portland Cement and Materials Company, at Sherman, St. Louis County, on Meramec River.

B. H. B. Straight's filter sand plant, Crystal City, Jefferson County. Washes and screens Mississippi River sand.

necessary to get out several screened grades of sand and gravel. At most of these plants the method of screening is a very simple one. The sand or gravel is elevated, usually by belt conveyor, to the top of a high screening tower (Pl. XI, A), where it is allowed to run by gravity over a series of inclined screens which separate the various grades, allowing each to fall into its own particular bin. A few of the plants get out only two grades, sand and gravel. Others are rigged for getting out several grades. At most plants, the material is screened wet. A stream of water (usually a four-inch one) is directed on to the topmost screen, washing the material down from screen to screen and washing out the fine silt entirely. A few plants screen the gravel dry. The most thoroughly equipped screening plants are at Hannibal on the Mississippi, and at Pacific, Drake, Sherman, and Valley Park, on the Meramec.

The plant at Osage City, which handles chiefly the grade known as roofing gravel, uses two cylindrical screens, which are placed on the dredge boat. The gravel is first delivered by the bucket dredge into a 3-16-inch rotary screen, the finer material going back into the river. From this screen it goes into a second rotary screen with a ¾-inch mesh, the coarser material being carried back into the river, and the desired material onto a barge. The gravel is washed during the screening. A plant similar to this was operated for a time on the Missouri at Boonville, but was abandoned because the gravel supply was so uncertain.

Those plants shipping unwashed St. Peter sand for glass manufacture, foundry, or fluxing purposes, usually crush the rock and then pass it through a screen which varies in size at different plants from ½-inch down to 20-mesh. Plants that wash the sand usually screen it twice. It is first crushed and then passed through a coarse screen, the larger lumps being returned to the crusher. After washing it is dried and again screened, usually through a 20-mesh, to get out any lumps that may be left.

DRYING SAND.

Sands used for structural purposes are not dried, but plants producing engine sand must be equipped with some sort of dryer. This usually consists of a furnace or stove much like the old-fashioned school house or station-room heater, around which is built a sheet iron jacket, leaving a free space of several inches between the jacket and the stove (Pl. XII, A). This space is

filled with sand which is fed in at the top. After the sand is dry, it is drawn off at the bottom of the jacket and loaded on cars or into storage bins. During average summer weather about 50 minutes are needed to dry the sand in a stove of 20 cubic feet capacity, but when the sand or the atmosphere is particularly wet, the process takes longer. The object of drying the sand is to make it run more freely from the sand domes of locomotives.

The sand used in glass manufacture is usually dried. The most successful method and the one used in most of the large plants seems to be that of a rotary dryer which uses gas or crude oil for fuel. The sand is slowly fed down an inclined cylinder through the dryer, the constant rotation keeping the sand in movement and exposing it more directly to the action of the heat. Another method employed is that of placing a series of steam pipes in the bottom of a large bin filled with sand from which the excess moisture has been allowed to drain off in bins arranged for the purpose. The sand is allowed to stand till dry, is then drawn off to the elevators, and the process repeated.

STORAGE OF SAND.

Inasmuch as sand does not deteriorate under the action of the weather, most producers of sand and gravel for structural work simply pile up the product during the summer for the winter trade. A few plants are equipped with storage bins, from which the cars are loaded by gravity. Plants producing engine sand, however, must be provided with storage bins, because this sand must be kept dry. Plants producing glass sand are also equipped with storage bins, but usually these are not capable of holding more than one or two days' output.

SELECTION OF GRADES OF SAND.

Plants not equipped to screen their output of sand for structural work can usually produce from one to four grades by a careful selection of the bar from which they dredge. Missouri River plants get out a coarse and a fine sand, the former being used largely for structural purposes, the latter for core sand and for asphalt sand in street paving. Gravel producers on Black River can, by proper selection, secure two sizes of gravel and two of sand. Where the bars are exposed, this is easy; but where the bars are under water, the operators must learn to prospect

A. Plant of J. H. Freeman, Newburg, Phelps County. Furnace for drying engine sand.

B. Thin bedded Everton sandstone along roadside; N. E. ¼ Sec. 26, T. 37 N., R. 8 E., north of River aux Vases, Ste. Genevieve County.

		1910		1911		1912
		Totals.	Per cent.	Totals.	Per cent.	Totals.
Glass	Tonnage	186,342	3.0	117,756	3.3	129,020
	Value	$130,686	9.8	$82,705	7.9	$81,817
Paving	Tonnage	×	×	41,610	1.1	60,814
	Value	×	×	$15,364	1.5	$16,897
Grinding and Polishing	Tonnage	×	×	101,239	2.8	×
	Value	×	×	$55,844	5.4	×
Moulding	Tonnage	79,977	1.3	92,679	2.6	106,983
	Value	$42,787	3.2	$49,522	4.8	$71,366
Building	Tonnage	2,525,600	41.3	1,982,751	55.0	1,817,110
	Value	$571,501	42.7	$533,722	57.2	$521,164
Fire	Tonnage	35,680	0.6	6,689	0.2	×
	Value	$16,420	1.2	$2,371	0.2	×
Engine	Tonnage	65,145	1.1	83,850	2.3	24,335
	Value	$12,544	0.9	$14,000	1.4	$5,478
Ballast	Tonnage	×	×	×	×	×
	Value	×	×	×	×	×
Gravel	Tonnage	3,070,012	50.3	1,145,701	31.9	1,193,667
	Value	$485,953	36.3	$259,263	24.9	$253,911
Miscellaneous	Tonnage	145,701	2.3	79,770	2.2	189,632
	Value	$79,628	5.9	$27,293	2.6	$58,766

× Concealed in totals

TION OF SAND AND GRAVEL BY USES.

	1913		1914		1915		1916		1917	
Per cent.	Totals.	Per cent.	Totals.	Per cent.	Totals.	Per cent.	Totals.	Per cent.	Totals.	Per cent.
3.5	130,676	3.2	160,190	4.5	145,920	5.5	163,706	4.8	153,970	6.7
7.5	$91,284	8.2	$112,484	11.0	$91,380	13.5	$121,692	13.8	$162,838	14.7
1.7	288,067	7.0	30,327	0.8	3,429	0.1	×	×	×	×
1.6	$69,451	6.3	$6,485	0.6	$2,550	0.3	×	×	×	×
×	124,583	3.0	102,568	2.9	136,737	4.7	138,141	3.8	×	×
×	$63,665	5.8	$54,263	5.3	$57,219	8.4	$66,438	7.5	×	×
2.9	132,415	3.2	53,837	1.5	41,284	1.8	161,788	4.4	90,811	3.9
6.6	$63,695	5.8	$26,656	2.6	$18,852	2.8	$61,972	7.0	$58,608	5.2
49.4	1,585,168	38.4	1,788,277	50.6	794,398	27.5	766,534	21.0	1,018,714	44.3
48.1	$526,912	47.5	$541,741	53.0	$248,225	36.7	$224,863	25.3	$449,596	40.8
×	×	×	4,486	0.1	×	×	×	×	×	×
×	×	×	$1,800	0.2	×	×	×	×	×	×
0.7	×	×	43,619	1.2	67,229	2.3	35,865	0.9	21,170	0.9
0.5	×	×	15,872	1.5	$19,970	2.9	$11,836	1.3	$9,289	0.8
×	425,282	10.3	×	×	×	×	937,572	25.7	95,096	4.2
×	$38,679	3.5	×	×	×	×	$118,856	13.4	$28,095	2.5
32.4	1,363,202	33.0	1,321,839	37.4	1,656,745	57.4	1,364,907	37.4	565,039	24.8
23.4	$232,831	20.9	$257,827	25.2	$226,716	33.5	$250,728	28.2	$183,860	16.6
5.2	20,833	0.5	×	×	43,469	1.5	74,692	2.0	329,267	14.4
5.4	$7,940	0.7	×	×	$10,772	1.6	$21,249	2.0	$209,459	19.0

for coarse and fine grades by using a long piece of iron pipe to distinguish between the grades by the compactness of sand on the bar.

Plants quarrying the St. Peter sandstone may occasionally find seams of coarser, sharper, and more completely recrystallized sandstone which is suitable for stone-sawers' sand. Such a product is secured from one of the quarries just east of Pacific. By using care in quarrying, impure ferruginous (red or yellow) seams and clayey (greenish) seams can be rejected, thereby greatly improving the grade of the commercial product.

CONDITIONS OF THE TRADE.

STATISTICS OF PRODUCTION.

The relative importance of sand and gravel among Missouri's mineral products for the past few years is set forth in the following table:

Comparative value of sand and gravel output.

Year.	Sand and gravel.		All other mineral products.	
	Value.	Per cent.	Value.	Per cent.
1910	$1,343,679	2.9	$44,103,765	97.1
1911	1,042,674	2.2	44,357,698	97.8
1912	1,083,704	2.1	49,504,222	97.9
1913	1,109,233	2.3	46,657,351	97.7
1914	1,020,903	2.3	42,564,764	97.7
1915	675,684	1.2	59,145,368	98.8

For each of these years sand and gravel together have ranked as the eighth item in value among the States' mineral resources.

The accompanying table gives the tonnage and value of the sand and gravel output classified according to uses. (Table facing this page.)

Production of sand and gravel by sources, 1913.

(Exclusive of chats.)

	Tonnage.	Value.	Average cost per ton.	Per cent weight.	Per cent value.
Missouri River	1,123,307	$321,488	$.286	35.3	31.4
Mississippi River	804,122	208,759	.259	25.3	20.4
Meramec River	545,032	143,502	.263	17.2	14.0
Other streams	218,813	57,168	.261	6.9	5.6
St. Peter sandstone	438,369	242,350	.555	13.8	23.7
Bank sand	44,754	49,955	1.116	1.4	4.8
Totals	3,174,397	$1,023,222	.322	99.9	99.9

MARKETS.

Throughout the State, especially in the Ozark region with its excellent stream gravels and sands, and to a lesser extent in the extreme northwest corner with its glacial sands and gravel, there is a heavy local production of which there is little record. In the small towns and on the farms, gravel and sand are hauled by the consumer himself, sometimes from his own property, more frequently from the property of others. In the Ozark region there is rarely any charge for sand or gravel secured in this way, and when there is a charge, it is not often over 5 or 10 cents a load. In other places, where material is not so abundant, the charge varies from 25 cents to $1.00 a load, depending on the local supply. In these localities, it is usually customary for the owner to keep the pit in good shape, do all necessary stripping, and maintain a fair road to the bank.

In many cities of intermediate size, sand and gravel are handled by the local dealer in fuel, lumber, or ice, or by owners of dray lines. In some of these places, building contractors or cement men conduct a sand business, chiefly for their own needs, but incidentally to supply also the small local demand. Occasionally, dealers ship sand to nearby towns, but for the most part they do only a local business.

In a few of the larger cities there are companies devoted exclusively to the production of sand and gravel. From 50 to 90 per cent of their output is usually consumed in the city where the company is located. At St. Louis, a considerable part of the output goes to nearby Illinois points; at Kansas City, a small part goes to Kansas points, but with these exceptions,

little building sand and gravel goes out of the State. A considerable amount of roofing gravel has gone south and west to Texas, Oklahoma, and Colorado. Sand and gravel, when sold at the plant and hauled by the consumer, varies in price from 50 cents to $1.10 per yard. When loaded on the cars for shipment at the larger plants, prices as low as 15 cents per ton have been reported. When delivered, the price usually ranges from $1.00 to $1.75 per yard, although in St. Louis and Kansas City delivery charges are based on the number of blocks the sand has to be hauled from the sand station. Prices depend also largely on local competition.

When sold in small quantities, sand is often measured by the bushel. A bushel is often spoken of by the dealer as a cubic foot, but, to be more exact, it is approximately 1¼ cubic feet, or about 22 bushels to the yard. Local dealers usually get 5 cents a bushel for sand. Strangely enough, one or two plants are shipping sand by this measure instead of by the yard.

Important shipping points of sand and gravel in the State are St. Joseph, Kansas City, Glasgow, Boonville, and Jefferson City on Missouri River; Canton, Hannibal, Louisiana, St. Louis, and Crystal City on the Mississippi; Osage City on Osage River; Poplar Bluff on Black River; Silica on Joachim Creek; and Pacific, Drake, Sherman, and Valley Park on Meramec River. When shipped in carload lots, sand and gravel are sold by the ton instead of by the yard, the relation of the ton to the yard varying with the specific gravity, the porosity, and with the moisture in the sand. Actual shipping weights have been variously reported from 2,300 to 3,400 pounds per yard by operators. Prices for building sand and gravel in carload lots, f. o. b. the plant, have varied in the past from 15 cents to $1.08 per ton, depending on the quality of the material, whether it is washed or unwashed, screened or bar-run, etc. Roofing gravel, when clean and well-rounded, commands a high price.

The price of sand depends largely on local competition at the point of consumption. Generally speaking, the actual cost of production depends on so great a variety of circumstances that any adequate discussion of the subject is impossible. Under the most favorable conditions, it can be put on the car for 10 cents a yard, or even less; but under the least favorable conditions, the actual cost may run above $1.00 per yard f. o. b. the plant.

Permission to dredge navigable streams must be secured

through the United States War Department by a petition setting forth the details of the proposed business. Owners of sand on unnavigable streams and owners of bank sands usually demand a royalty, which varies from one cent a yard to 25 cents, depending upon the local supply and particularly upon the advantage of location. A few large producers own their own banks or bars. Others pay an annual rental, regardless of the amount of production, while still others not only pay a royalty but also pay damages where riparian rights are interfered with.

The following table gives the average prices received per ton for various grades of sand and gravel put out by Missouri producers during the years 1910-1917 inclusive:

Average prices per ton of sand and gravel.

	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.
Glass	$.702	$.702	$.634	$.698	$.702	$.625	$.743	$1.057
Paving	.....	.369	.278	.233	.213	.743	.340	.....
Grinding and polishing	.....	.552	.....	.511	.529	.418	.481	.....
Moulding	.535	.534	.667	.482	.495	.456	.383	.645
Building	.226	.269	.287	.332	.302	.311	.293	.441
Fire	.459	.354	.....	.....	.401	.....	.250	.....
Engine	.192	.....	.225	.....	.363	.297	.330	.438
R. R. ballast	.....	.....	.....	.091	.....	.....	.231	.295
Gravel	.158	.226	.213	.171	.195	.137	.183	.325
General average	$.219	$.289	$.295	$.269	$.289	$.234	$.241	$.484

COMPETITION FROM POINTS OUTSIDE THE STATE.

In the vicinity of Kansas City and in the west central part of the State in general, sand dealers have keen competition with Kaw River sand shipped in from Kansas. Many users say that this sand is cleaner and coarser than Missouri River sand, and it brings a price from 15 to 50 cents a yard higher. In the extreme northwestern portion of the State, dealers handling local glacial sands or Missouri River sands from St. Joseph are forced to compete with Platte River sand shipped in from Nebraska. This sand is also said to be coarser and cleaner than the local sands, and it brings several cents more on the market. In addition to this, local dealers say that dredging conditions on the Platte are such that the companies there can sell sand five to ten cents a ton cheaper f. o. b. the plant than can Missouri River companies. Dealers in the northeast counties must compete to some extent with sand from large plants at Keokuk, Iowa.

The intrinsic value of sand is so low and the product so bulky that the cost to the consumer lies largely in the handling and in railroad charges. The latter are so great in proportion to the first cost that, except in the case of high-grade sands for special purposes, sand and gravel can not be shipped great distances. A good local supply, therefore, particularly of sand, becomes of vital importance to the structural trades. This is less true of gravel, because crushed rock, which can be used instead, is available at so many points.

THE GLASS SAND MARKET.

Because of the high degree of purity necessary in sand for the manufacture of glass, deposits suitable for this purpose are relatively rare. As a consequence, the market conditions are quite different from those obtaining for other kinds of sand.

At present, the total production of glass sand from the State is limited to the St. Peter formation, although in places the Robidoux may be capable of yielding glass sand. The St. Peter formation outcrops in a narrow belt beginning at the west side of Montgomery County and extending east and southeast through Montgomery, Warren, St. Charles, Franklin, St. Louis, Jefferson, Ste. Genevieve, Perry, and Cape Girardeau counties. An important inlier is also exposed in Lincoln County. At present, however, production comes only from that part of the belt lying between Klondike in St. Charles County and Crystal City in Jefferson County.

As practically all of the producers own the properties upon which they are operating, no data are available regarding leases or royalties. The actual cost of production varies greatly, depending largely on the processes of crushing, washing, screening, drying, etc., through which the sand may be put. It depends also on the thickness of the overburden to be stripped, the degree of friability, the expense of getting a water supply, and other special conditions of quarrying. Under the most favorable circumstances, sand can be put on the cars crushed and screened, but not washed or dried, for about 25 cents per ton actual cost; but under less favorable conditions of quarrying, a washed and dried sand costs about 90 cents a ton. These are extremes, and it must be borne in mind that general figures of this sort mean little unless local quarrying conditions are known. These figures also vary with the varying wages paid to laborers.

Two of the large producers in the State consume practically all of their output at their own glass factories. Some of the St. Peter sand goes to Herculaneum for flux. Large quantities go to St. Louis, Kansas City, and to other places to be used for core and moulding sand, for furnace linings, and for the manufacture of refractory brick and of glass. Shipping points outside the State are Granite City, East St. Louis, Alton, and Belleville, Illinois; North Vernon, Indiana; Caney and Coffeyville, Kansas; and places in Texas and Oklahoma. Most of the St. Peter sand shipped outside of the State is used for glass production, but smaller quantities are also used for flux, core sand, and for refractory purposes. The glass factories of the Kansas gas belt (Caney and Coffeyville), and those of the southern Illinois coal fields (Alton) draw heavily on the output of Missouri glass sand.

CHAPTER III.

THE USES OF SAND AND GRAVEL.

BUILDING SAND AND GRAVEL.

The importance of sand and gravel used for building purposes is indicated by the fact that during the year of 1913 it constituted about 71 per cent by weight, and about 67 per cent by value, of the total State production of sand and gravel. Structural sand and gravel includes sand for mortar in plastering, brick masonry, and stone masonry; sand and gravel for concrete aggregates; sand for sand-lime brick; and gravel for roofing purposes.

SAND FOR MORTAR.

Mortar for use in plastering, brick laying, and stone masonry may be defined as

> "A mixture of cement or lime and sand or other fine aggregate having water added so as to make it like a paste."[1]

MORTAR FOR PLASTERING.

In selecting a sand for plastering purposes, cleanness, size of grain, sharpness, and color are properties of sufficient importance to warrant inspection. In discussing specifications for mortar sand, Condra[2] says,

> "All sand used for mortar should pass a No. 10 sieve and 80 per cent of it should be retained upon a No. 74 sieve. It should be a silicious sand, as sharp as can be obtained within reasonable limits of cost. It should be free from all vegetable or organic matter, and should not contain more than 10 per cent by weight of clay or loamy material."

Cleanness is one of the most important properties to be desired in a good sand for plastering. It has already been shown that clay in moderate amounts is not harmful in sand for concrete work[3] unless it occurs in the form of a coating on the

[1] Taylor, F. W., and Thompson, S. E., Concrete, plain and reinforced; 2d ed., p. 2d, 1911.
[2] Condra, G. E., The sand and gravel resources and industries of Nebraska; Nebraska Geol. Survey, vol. III, pt. 1, p. 150, 1908.
[3] Sabine, L. C., Cement and concrete, 2d ed., p. 182, and p. 271, 1907.

individual grains, in which case it prevents proper adhesion of the cement or lime to the sand grains. Sand in which the grains are so coated should be washed.

In plasters for the interior of reservoirs and other structures where water proof finish is desired, clay in small quantities (under 10 per cent) has been found desirable.[1]

The presence of vegetable matter in the form of humus coating the grains of sand has the same effect as clay[2] and renders a sand unfit for use in the best work. Peat or lignite in the sand has no apparent effect upon the strength of mortar, but is highly injurious to plastered walls, since it causes the surface of the plaster to pop, leaving small pits.

Sands from Missouri River, and to a lesser extent from the Mississippi below the mouth of the Missouri, are open to much complaint, as a result of lignite. Other organic matter is not usually present in creek and river sands to an appreciable extent, neither is there much trouble about clay films on the grains. Clay is present to an objectionable degree in the glacial sands of the northern part of the State and to a less extent in the Tertiary bank gravels and sands of the southeastern lowland region, and these sands, to yield the most satisfactory results, should be washed.

Size of grain is also of considerable importance in plastering sand. There should be no grains of greater diameter than the thickness of the desired coat of plaster, since they would interfere with the spreading of the mortar, and leave an irregular surface. All grains should pass a No. 10 sieve, according to Condra[3]. A preponderance of very fine grains is also said to be undesirable, since the plaster does not "clinch" well behind the lath, but "falls through." A fine sand is also more difficult to mix. According to the same authority 80 per cent of the sand should be retained on a 74 mesh sieve.[4]

A sand of graded grains has a lower per cent of voids, and hence requires less lime or cement, than an ungraded sand, and has a greater strength.[5] This feature is of less importance, however, in plaster work than in concrete aggregate, since the

---

[1]Taylor, F. W., and Thompson, S. E., Concrete, plain and reinforced, 2d ed., p. 343, 1911.

[2]Taylor, F. W., and Thompson, S. E., op. cit., p. 154b and 154c.

[3]Condra, G. E., loc. cit.

[4]Condra, G. E., op. cit., pp. 150 and 152-153.

[5]Condra, G. E., op. cit., pp. 149-150.

mixture used in plastering contains no coarse aggregate at all and the opportunity for grading is consequently much less.

St. Peter and Roubidoux sands are too fine for the best plastering work, as are also the finer sands from Missouri River. Most other sands in the State are sufficiently coarse; in most cases requiring the screening out of the coarsest pebbles. Missouri, Mississippi, and Meramec sands are extensively used for plastering purposes.

Sharpness is a property universally demanded in specifications in the past, but recent tests seem to show that its importance has been highly over-emphasized. The Bureau of Standards reports that round sand is as good as sharp sand.[1]

Color is of very little importance, except in finishing coats, where great whiteness is desired. For practically all ordinary work any of the sands secured in the State are satisfactory in color. Where whiteness of surface becomes a desirable feature, the St. Peter sand has sometimes been used. It is rather fine-grained for plastering work, but is the whitest sand in the State.

MORTAR FOR BRICKLAYING.

What has just been said about mortar for plastering is true in general of mortar for bricklaying with only slight modifications. Since mortar in brick work is forced, as a rule, to undergo greater strain than in plaster work, strength is here an item of greater importance. Films of clay or organic matter on the grains are to be guarded against even more carefully than in plastering work. Small amounts of clay evenly distributed through the sand are not harmful. Lignite is less harmful in a solid wall than on a plastered surface since there is less surface to undergo the popping described above.

Size of grain is important. No pebble in the sand should have a diameter as large as the mortar joint, which usually runs from ¼ to 3-8 of an inch. Up to this limit, however, the coarser the sand, the stronger the mortar, according to principles already laid down. A graded sand is to be desired, since it requires less cement or lime and yields a stronger mortar.[2]

Sharpness and color are apparently matters of little consequence in mortar for brick work.

---

[1] Circular No. 45, p. 36, 1913.

[2] Taylor, F. W., and Thompson, S. E., Concrete, plain and reinforced, 2d ed., p. 205, 1911.

MORTAR FOR STONE MASONRY.

Mortar for stone masonry follows closely the specifications of that for brick laying. Since the joints are usually thicker than in brick work the size of pebbles allowable in the sand is somewhat greater. Lignite is even less harmful than in brick laying. Other factors of cleanness and size tending to influence strength of mortar are equally important in either kind of work, and color and sharpness are negligible.

SAND AND GRAVEL FOR CONCRETE AGGREGATE.

By far the greater proportion of the sand and gravel used in the structural trades is employed in concrete work, and consequently properties required in a concrete aggregate are outlined in some detail.

PROPERTIES DEMANDED IN GOOD CONCRETE AGGREGATE.

The following summary of properties desirable for good concrete aggregate is quoted from Taylor and Thompson.[1]

"Tests of the sand, unless it comes from a bank which has been previously tested, are as necessary as tests of the cement. (159.)

"Even a small amount of vegetable matter in sand prohibits its use. (154b).

"Fine sand, even if free from vegetable matter, makes a much weaker concrete than coarse sand. If it is necessary to use fine sand, therefore, the proportion of cement should be increased. (136, 159a).

"If the grains are mostly less than 1-32 inch in diameter, nearly double the amount of cement should be used than with an equally clean sand having mixed grains running up to ¼ inch, in order to obtain equal strength. (159a).

"For unimportant work, fine sand, if clean, may sometimes be used, but it is usually cheaper to import a coarse sand and use leaner proportions. (149, 159a).

COARSE AGGREGATE.

"If the stone contains dust, it must be uniformly distributed throughout the stone, and the proportion smaller than ¼ inch should be determined by test and considered as sand when proportioning. (34).

"Soft stone should be avoided in important structures. (390).

"Gravel if used, must be clean, that is, the particles must be free from coating of vegetable matter or clay which will retard the setting or prevent the cement from sticking to the pebbles. (34, 386).

"Gravel can be washed satisfactorily only with special apparatus. (250)."

Among the properties to be considered in discussing the value of a given sand or gravel in concrete construction, the

[1]Concrete, plain and reinforced, 2d ed., pp. 1a-2a, 1911. The numbers in parentheses refer to the pages in the above treatise, where these properties are discussed in detail.

following have been thought to be of sufficient importance to warrant specific consideration: cleanness, size of grain, volume of voids, shape of grain, smoothness of grain, strength of aggregate.

Cleanness in concrete aggregates.—It has formerly been believed that the presence of clay in concrete aggregates was undesirable, and that to secure the best results aggregates carrying clay should be washed or screened or both, before they are used. In modern practice, it is believed that clay in moderate amounts is not harmful; in fact, clay is now sometimes added to increase the plasticity, to increase the ease in tamping the mass, or to render the mortar stiff that it may withstand early immersion.[1] One of the results of the presence of clay is to retard the setting of the concrete. With natural cement, ten per cent of clay produces a marked retardation, while with Portland Cement, larger amounts are necessary before the action becomes appreciable.[2] Concerning the strength of the concrete, the same writer concludes that clay in quantity up to at least 6 per cent of the aggregate increases the strength of Portland concrete, while natural cement concrete is not appreciably affected.[3] Clay to the amount of 10 to 25 per cent of the total may be added to lean mixtures of Portland concrete, thereby increasing its strength and its ability to withstand early immersion.[4] It is generally believed that argillaceous matter should be avoided in concrete that is subject to action of sea water.[5] Pure clay has been found to have a certain value in rendering concretes and mortars waterproof.[6]

From these statements, it may be seen that for most purposes the presence of considerable clay is not harmful. Most sands put on the market in this State are sufficiently low in clay content to fill most demands. The glacial sands and gravels of Nodaway County, the Tertiary bank sands of Crowley's Ridge, and Missouri River sands where carelessly selected, sometimes run rather high. At a few places, although the clay content is low, gravels show a clay film over the individual pebbles, a more harmful feature than a much higher clay content in a completely disseminated form. Gravels in which the sur-

[1]Sabin, L. C., Cement and concrete, 2d ed., p. 267, 1907.
[2]Loc. cit.
[3]Op. cit., pp. 319-320.
[4]Op. cit., p. 271.
[5]5 Op. cit., p. 364.
[6]Taylor, F. W., and Thompson, S. E., Concrete, plain and reinforced, 2d ed., p. 343, 1911.

face of the individual grains is dirty should be washed, because this coating may very seriously interfere with the proper adhesion of the cement with the sand grain or pebble. This clay film, while noted in a few creek gravels, is more common in the glacial gravels in the northwestern part of the State, and in the Tertiary gravels of Crowley's Ridge in southeast Missouri. For important structures these should be washed.

The presence of organic matter in aggregates is universally condemned. Sabin says,[1]

"There seems to be no doubt that loam, peaty matter or humus will very materially decrease the strength of mortars, or even destroy them entirely."

Taylor and Thompson say:[2]

"When the impurities are of an organic nature, like vegetable loam, they frequently have been found to prevent the mortar or concrete from hardening or to retard the hardening for so long a period as to make the sands entirely unfit for use. A very minute quantity of vegetable matter may produce injury, so small a percentage in fact that frequently a sand which has passed careful inspection fails in practice to set properly with any brand of cement; therefore a test is absolutely necessary for any sand which has a suspicion of organic matter."

Speaking of the fall of a concrete building, the authors go on to say:

"The cause of the failure was traced in the expert investigation, to vegetable impurities in the sand which had washed down into the bank from the soil above. The poorest sand **** showed by mechanical analysis only 4% by weight of fine material passing a No. 100 sieve and 1.61% silt by washing, but this silt was found to contain nearly 30% of vegetable matter corresponding, however, to only 0.5% in the total sand. The vegetable matter appeared to coat the grains of sand so as to prevent adhesion of the cement and also retard the setting."

The above statement seems to be meant to apply only to humus substances. Whether or not coal or lignite, which are much more nearly inert, would have the same effect, is doubtful. That the lignite in Missouri River sands causes the "popping" of the cement or plaster surfaces, as already described (p. 11), is well attested by observations. The writer has, however, been assured by many dealers and by a few builders that the lignite in the quantities usually present is not harmful in a solid mass of concrete or masonry, but he has not been able to find any scientific data on the point in question. No tests for organic matter have been made on the sands examined for this report.

The following specifications regarding cleanness are essenti-

[1]Cement and concrete, 2d ed., p. 182, 1907.

[2]Concrete, plain and reinforced, 2d ed., pp. 154b-154c, 1911.

ally those adopted by the joint committees on Concrete and Reinforced Concrete (1900) and the report of the Reinforced Concrete Committee (1909) of the National Association of Cement Users.[1]

"The gravel shall be composed of clean pebbles free from sticks and other foreign matter and containing no clay or other material adhering to the pebbles in such quantity that it cannot be lightly brushed off with the hand or removed by dipping in water. It shall be screened to remove the sand, which shall afterward be remixed with it in the required proportions."

According to the Bureau of Standards[2] the presence of organic matter, sulphides, and soluble alkalies are to be avoided in a sand or gravel. From the mode of formation of sands, it follows naturally that most sands will be free from sulphides and soluble alkalies, because they would weather out in the process of formation. They are more apt to occur in crushed rock aggregate. Organic matter, however, is often present in sands.

Size of grain in concrete aggregate.—The principle has already been emphasized that in a general way the larger the size of grain in an aggregate, the stronger the resulting concrete, because each individual grain has a larger surface to which the cement may adhere.[3] The coarsest particles, however, should not be large enough to separate from the mortar during laying, nor to prevent the concrete from fully surrounding the reinforcement or filling all parts of the forms. For use in large masses, pebbles up to 3 inches are allowable. For reinforced work, they should usually pass a one-inch ring.[4] Even large bowlders may be laid in heavy concrete walls without detriment, if only they are perfectly bedded in the concrete and not set too close together.[5]

It has also been found by actual experiment that fine sand requires a larger percentage of water in gaging than does coarse sand; when moist it has a higher percentage of voids and consequently a less density, because the grains are separated by a water cushion (See page 28). For that reason, very fine sand requires a higher proportion of cement to make a proper mixture.[6] The following recommendation was made by the

[1]Taylor, F. W., and Thompson, S. E., Concrete, plain and reinforced, 2d ed., p. 34, 1911.
[2]Circular No. 45, pp. 35-36, 1913.
[3]Sabin, L. C., Cement and concrete, 2d ed., pp. 173-174, 1907.
[4]Taylor, F. W., and Thompson, S. E., op. cit., p. 43, 1911. Specifications of the Joint Committee on Concrete and Reinforced Concrete (1900) and the Report of the Reinforced Concrete Committee (1909) of the National Association of Cement Users.
[5]Sabin, L. C., op. cit., p. 374, 1907.
[6]Taylor, F. W., and Thompson, S. E., op. cit., p. 147, 1911.

Reinforced Concrete Committee of the National Association of Cement Users.[1]

"The relative strength of mortars from different sands is largely affected by the size of the grains. A coarse sand gives a stronger mortar than a fine one, and generally a gradation of grains from fine to coarse is advantageous. If a sand is so fine that more than 10 per cent of the total dry weight passes a No. 100 sieve, that is, a sieve having 100 meshes to the linear inch, or if more than 35 per cent of the total dry weight passes a sieve having 50 meshes per linear inch, it should be rejected or used with a large excess of cement."

According to the Bureau of Standards (Circular No. 45) fine aggregates should pass a ¼-inch mesh screen.

A knowledge of effective size and of uniformity coefficient is of considerable value in getting a conception of size and voids of any particular sand. Since, in general, coarse sands are less uniform in size than fine, it is rather generally true that the larger the uniformity coefficient, the coarser the sand and the better for concrete work. A sand with a coefficient above 4 or 5 is a good coarse sand for this type of work.[2] However, a sand with even a moderately low coefficient may be used if the effective size runs high. The bulk of the sand used in the State is pumped from Mississippi, Missouri and Nodaway Rivers, and the uniformity coefficient of these sands runs somewhat lower than the figures given above. Other sands come largely from the screenings of gravels, in which case the proportions of coarse and fine can be easily regulated. Meramec River produces much sand screened from gravels.

Voids in concrete aggregate.—As all voids in the coarse aggregate may be considered filled with the mortar (itself a mixture of sand, water, and cement), it becomes apparent at once that the lower the percentage of voids in the gravel aggregate, the less cement will be required in the mixture to give the same strength. Actual tests show that a thoroughly graded aggregate gives a concrete with an increase of about 14 per cent of strength and a decrease of about 12 per cent in the cement used over the same materials ungraded.[3]

As has been previously shown (p. 22) the lowest percentage of voids is to be secured by such a grading of aggregates that all the voids of each sized grain contain the largest particles

[1]Taylor, F. W., and Thompson, S. E., op. cit., p. 159a.
[2]Op. cit., p. 182.
[3]Taylor, F. W., and Thompson, S. E., op. cit., p. 205.

that will enter them.[1] To secure approximately this condition in sands, Feret[2] has screened sand into,

Coarse 5 mm. – 2 mm. (0.20 –0.079 in.) diameter
Medium 2 mm. – ½ mm. (0.079 –0.026 in.) diameter
Fine less than ½ mm. (0.020 in.) diameter

and recombines them in proportions,

"in which there are no medium grains, and in which coarse grains are found in a proportion double to that of fine grains, cement included."

If the grains of each successively smaller size are too large to enter the voids of the size larger than themselves, they will hold the larger pebbles apart, thus increasing instead of decreasing the total voids.[3] For this reason, the grading of sands and gravels should be done scientifically, and too many or too coarse intermediate grades are not desirable. The size of the largest pebbles used in the aggregate will determine both the number and size of grades to be separated. These will then be recombined in the proportions that will give the lowest voids. These proportions may be determined by experiment, or by determining the volume of voids in the coarsest grade and using the proper volume of the next finer grade to just fill these voids. It seems wholly probable that where the coarser material used becomes as large as gravel, at least three grades of coarseness become necessary to produce the minimum voids, or in other words, the maximum density.[4]

It but rarely happens that bank or bar sand or gravel runs constant in its proportion of coarse or fine throughout any considerable part of its mass, and it still more rarely happens that these proportions in nature are such as to give the minimum of voids. For this reason, it is desirable to install screening plants in localities where sands and gravels are used largely in concrete construction, especially in work where a high degree of strength is required; and as washing involves but small additional expense, both screening and washing of gravels are usually to be commended where there is a large consumption.

Meramec River plants are equipped to wash and screen large quantities of gravel, chiefly for the St. Louis market. At these plants, the various sizes are sold separately and average about as shown in the table below.

---

[1]Taylor, F. W., and Thompson, S. E., op. cit., p. 160.
[2]Op. cit., pp. 143-148.
[3]Op. cit., p. 189.
[4]Op. cit., p. 148.

Commercial sizes in gravel and sand.

	Through.	On.
Concrete	2½ in.	1½ in.
Binder	1½ in.	¼ in.
Roofing	¾ in.	¼ in.
Torpedo	¼ in.	⅛ in.
Sand	⅛ in.	.....

These sizes are also slightly modified by putting out grades known as coarse and fine torpedo, coarse and fine roofing, etc. So far as the writer knows, no plants in the State are putting out ready-prepared graded aggregates. The various sizes sold separately by the plants are either used as put out, with the addition of the necessary sand by the builder, or else are graded on the ground where used. Close inquiry leads to the belief that few cement users in the State employ scientifically graded aggregates.

Shape of grain in concrete aggregate.—Sharp sands have heretofore been almost universally demanded in specifications, but in many localities, sharp sands are not to be had except at great expense. Many tests have been made, which show that rounded grains give results wholly satisfactory. There is little doubt though that, with all other conditions equal, angular to sharp grains give a slightly stronger concrete.[1] It must be borne in mind, however, that round sand has from 2 per cent to 5 per cent less voids than the corresponding sharp sand,[2] and decrease in voids is to be desired.

"———While sharpness of grain may exert a certain influence it is of so much less importance than the size of grain that the requirement of sharpness for sand should be omitted from concrete specifications."[3]

Angular fragments bond better than rounded, but on the other hand tend to bridge, leaving voids in the finished concrete.[4] Sharp sands are not abundant in the State, the sharpest being those screened from the chert gravels of the Ozark streams. Mississippi and Missouri sands are more rounded.

Smoothness of grain in concrete aggregate.—It is perfectly manifest that the nature of the surface of individual grains or

[1]Sabin, L. C., Cement and concrete, 2d ed., pp. 171-2, 1907.
[2]Taylor, F. W., and Thompson, S. E., Concrete, plain and reinforced, 2d ed., p. 174, 1911.
[3]Taylor, F. W., and Thompson, S. E., op. cit., p. 154a.
[4]Sabin, L. C., op. cit., p. 204, 1907.

pebbles will have some bearing on the value of an aggregate. The cement will adhere more readily to a rough than to a smooth surface, and all other factors being equal, an aggregate the pebbles of which have roughened surfaces will produce the strongest concrete.[1] There seems to be little data available on the actual effect of smooth pebbles in concrete. Sabin[2] says in discussing crushed rock versus gravel for aggregate that

"Gravel makes a good aggregate, although its surfaces are too smooth and rounding to give the best results."

Baker[3] complains of the flint gravels of the Ozarks, because of their tendency to check, and especially because of their very hard, smooth surfaces, to which, as he says, the cement will not adhere well. Results of tests made by the Bureau of Standards at Washington, and conducted at the request of the Missouri Bureau of Geology and Mines, seem to show that flint gravels are satisfactory for concrete work. The results of these tests are summed up on pp. 194-198 of this report. These smooth flint gravels are being used extensively in St. Louis, apparently with good results, and engineers have expressed it as their opinion that by proper grading first class concrete can be made of this gravel.

Strength of pebbles in a concrete aggregate.—In structures where little strength is required, the strength of the individual pebbles of the aggregate usually need not be considered. Where structures are subjected to severe tests, care should be taken to use gravels only, the pebbles of which are themselves strong.

"Evidences that chemical decay is going on in the grains would indicate that the sand is of very inferior quality."[4]

In most well-worn creek sands and gravels, there is usually little need to examine for chemical decay, especially in the Ozark region where flint gravel is the rule. On the other hand, the glacial gravels of northwest Missouri (typically exposed in Nodaway County) being from a much older drift than the well-known and much-used glacial gravels of our northern States, are in a much more advanced stage of decay. Granite and basic igneous pebbles are frequently so badly rotted as to be easily crushed in the hand. Thorough screening and washing, however, would probably remove much of the more seriously decayed material. It is believed that these gravels, though

[1]Baker, I. O., A treatise on masonry construction, 8th ed., p. 103, 1895.
[2]Sabin, L. C., Cement and concrete, 2d ed., p. 200, 1907.
[3]Baker, I. O., loc. cit.
[4]Sabin, L. C., op. cit., p. 169, 1907.

used locally for less important work, ought not be used where great strength of concrete is demanded.

Pebbles of shale or other soft material should be avoided in aggregates, as should also slate or other pebbles, in which there is a marked tendency to cleavage. For the same reason, and owing to its poor adhesive surfaces, mica is a harmful ingredient in sands, at least if present in quantities much in excess of 2 per cent.[1] It also increases the percentage voids.

USES TO WHICH CONCRETE IS PUT.

So large a proportion of the output of building sand and gravel is used in concrete construction that a brief statement may not be amiss as to the wide range of uses to which concrete may be put. Whether used alone, or reinforced with steel framework built into the mass, concrete is coming into use in a large variety of monolithic construction.

Culverts and even bridges of moderate size, along both public highways and railroads, are now frequently being built in one piece, from concrete, which is admirably adapted to this type of construction. In the Ozark region where sand and gravel are so abundant, the many small streams now crossed by fords could be easily and cheaply bridged with concrete arches. Indeed, this type of construction is now beginning to be employed in south Missouri. Where, as in many cases, the concrete is mixed by unskilled workmen, care should be used to see that the finished structure is not full of empty pores, a defect which seems to be one of the most serious made in rural bridge and culvert construction.

Tanks, reservoirs, sewers, subways, tunnels, and dams are being successfully constructed from concrete. The use of concrete dams should be of interest to those looking forward to the development of power on the numerous Ozark streams, where sand and gravel is extremely abundant. Some engineers recommend a small addition of clay to concrete for this type of work to give a degree of waterproofing.

For foundations, especially for those supporting heavy superstructures, monolithic concrete construction is recommended by most engineers.

Concrete, or "grout," houses are less frequently built now than formerly, for concrete blocks have superseded the mono-

[1]Taylor, F. W., and Thompson, S. E., Concrete, plain and reinforced, 2d ed., p. 154c, 1911.

lithic or "grout" type of construction. Heavier structures, especially grain elevators, silos, etc., are frequently built of reinforced concrete.

Sidewalks in most towns and cities are now being built almost exclusively of cement. In the building of sidewalks sand or gravel is used as a sub-base, as well as in the actual concrete construction. Buckley, in a report (No. V, 2d ser.) of this Bureau gives the specifications used in St. Louis, Kansas City, St. Joseph, and Jefferson City for cement sidewalks, curbs, and gutters.

Cement concrete is also being used for fence posts. Usually wooden blocks or strips are set into the mould and built into the post in order to furnish a surface to which wire can be attached. Other schemes have also been tried. In the western plains region where timber is scarce, this type of post is being widely used. It should have a demand in northern Missouri, but will not be extensively used for a long time to come in the more wooded Ozark region.

Experiments have also been made in the use of concrete for telephone poles and for railroad ties. In neither case do the experiments seem successful enough to give much encouragement.

ROOFING GRAVEL.

In the construction of flat or gently sloping roofs, especially in cities and on railroad construction, there is a heavy demand for roofing gravel. As produced by most plants, roofing gravel is so screened as to pass a ¾-inch screen and be retained on a ¼-inch screen. One company reported its roofing gravel as from ½ to 1 inch. This latter is unusually coarse. Several companies put out grades known as fine and coarse roofing, varying slightly from the standard given. The gravel must be coarse enough not to be carried off the roof when the sun is hot enough to cause the tar to flow, and must be sufficiently rounded not to cut through the tar-paper bed of the roof. The chief production comes from Osage and Meramec Rivers. The average selling price was 38 cents a ton for 1913, the maximum price reported was $1.08 per yard at the plant.

SAND FOR THE MANUFACTURE OF SAND-LIME BRICK.

Sand-lime brick consist of a mixture of quartz sand and pure lime, heated for 10 to 14 hours under a steam pressure of about 150 pounds. The binding material consists of a calcium silicate which holds the sand grains together. So far as the writer can ascertain, there are no plants in the State manufacturing this product. Exhaustive researches show that the brick are well suited to all ordinary structural demands.

Pure calcium lime is better than dolomitic lime for the process. The sand should be reasonably pure. Clay in amounts up to 10 per cent is not injurious, and a small amount adds to the ease with which the brick are moulded. Feldspar in quantities up to about 10 per cent is thought not to be a harmful ingredient. No data could be found regarding the use of ferruginous sands. Sands should be rather fine, ranging between 40 and 150-mesh, with the greater bulk lying between 60 and 100-mesh. Sand should constitute from 90 to 95 per cent of the batch.[1]

According to data furnished by Coons,[2] the sand would be better to be moderately sharp and free from alkalies. The St. Peter sand is ideally suited for the manufacture of sand-lime brick, practically all of it is more than sufficiently pure, and runs close to the theoretical fineness demanded (see Mechanical Analyses). Its only defect is its lack of sharpness, and this does not seem to be an essential property.

PAVING SAND.

During 1913, paving sand made up about 7.0 per cent of the tonnage and 6.3 per cent of the value of the sand and gravel produced in the State. During that year it averaged $.233 per ton. Most of that marketed was for asphalt work.

Pavements of a permanent character should consist of three portions, the foundation, the cushion layer, and the wearing surface.[3]

---

[1]Condra, G. E., Sand and gravel resources of Nebraska, Nebraska Geol. Survey, vol. 3, pt. 1, pp. 178-185, 1908.

Parr, S. W., and Ernest, T. R., A study of sand-lime brick, Illinois Geol. Survey, Bull. No. 18, 1912.

[2]Coons, A. T., Mineral resources of the U. S. for 1904, p. 1154.

[3]The matter of Public Roads in the State is treated somewhat more fully in Report No. V of the 2d series, published by this Bureau and written by E. R. Buckley, former State Geologist.

SAND AND GRAVEL FOR PAVEMENT FOUNDATIONS.

Although many pavements are laid directly upon the subgrade without any special foundation, the best practice for permanent pavements demands some special foundation unless the subsoil is of a particularly favorable character. Foundations vary considerably. Usually, the most permanent and ultimately the most satisfactory foundation is concrete. For sheet asphalt pavement, concrete is almost indispensable and is often used for brick, wood-block, or stone-block work. Sand and gravel for concrete pavement foundations demand essentially the same specifications as for other types of first-class concrete work. These have already been given.

A mixture of gravel and sand is often used as a foundation for brick or wood pavements. The mixture is laid loose and is compacted by rolling. The layer should be from 6 to 12 inches thick, depending on the traffic, the nature of the soil, and the drainage.

Sometimes sand without gravel is used, especially for stone-block pavements, the sand not only making a good bed in which to lay the thick and thin stones, but also making it much easier to maintain the proper level of the surface of the blocks.[1] The sand or gravel should preferably be reasonably sharp, because sharp sand rolls less and binds better. In order to insure proper drainage, sand and gravel for pavement foundations should never contain more than 15 to 20 per cent of clay.[2]

SAND FOR THE CUSHION LAYER.

In brick, stone, and wood-block pavements, there is usually between the foundation and the wearing surface a thin layer (½ to 2½ inches) of sand known as the cushion, its purpose being to secure a uniform bearing for the blocks and to insure suitable bedding for uneven blocks. The sand should be fine and without pebbles, so as to give a soft, smooth surface. It should be free from loam and vegetable matter which might decay or be washed away, thus allowing the pavement to settle;[3] it should be sharp, as sharp sand is less mobile; and it should be dry enough to pack well.

[1] Baker, I. O., A treatise on roads and pavements, 2d ed., p. 384, 1914.

[2] Buckley, E. R., Public roads, Missouri Bureau of Geol. and Mines, vol. 5, 2d ser., p. 42, 1907.

[3] Baker, I. O., op. cit., pp. 497-8, 536-7.

The finer grades of Missouri and Mississippi river sand are used for this purpose. Although they are not sharp, and although they must also be watched for clay, they are about the best sands available. St. Peter sand and Roubidoux sand could be used, as they have all the desirable properties except sharpness.

SAND FOR ASPHALT PAVEMENTS.

In asphalt pavements, sand makes up about 90 per cent of the wearing coat. The sand should be clean, because clay or vegetable matter tends to prevent the asphalt from properly adhering to the grains. This applies more to the condition of the individual grains, which should be free from a coating, than to the presence of small quantities of finely divided clay, which in itself is not particularly harmful. Angular grains give slightly better adhesion, but are desirable especially because less mobile. The individual grains should be hard in order not to crush under constant traffic. A rather pure quartz sand is best. A graded sand is to be desired, because it is lower in voids, and because it takes less asphalt.[1] [2]

The above references are not wholly in accord in regard to the size of the sand. Buckley specifies coarse sand. Baker on the other hand makes a less definite statement. He says:

"Fine sand is usually less sharp than coarse, and the finer the sand the greater the surface to be coated, and hence the greater amount of asphalt required. ****On the other hand, the smaller the voids, the greater the binding action of the cement; and also the finer the sand the smaller the voids, although the per cent of voids may be greater than with sand having grains of graded sizes."

He concludes, however, that a graded sand is probably most satisfactory. The finest grade of Missouri River and Mississippi River sand is used for asphalt rather extensively in practice.

Richardson,[3] who ranks high as an authority on asphalt pavement work, says:

"***Unfortunately we know too little in regard to the cause of the varying character of the particles composing the quartz sand which is used. We have not been able to tell why a certain Missouri River sand produces such a mushy mixture and is so unsatisfactory that its use had to be abandoned, or why a Platte River sand is possessed of peculiarities seen in that from no other river.

"Difference in the shape of the grain and in the character of its surface are the probable causes, and these characteristics of a sand are, therefore,

---

[1]Baker, I. O., op. cit., p. 411.
[2]Buckley, E. R., op. cit., p. 48.
[3]Richardson, Clifford, The modern asphalt pavement, pp. 31-32, 1910.

probably next in importance to the composition and size of the grains in determining its suitability for paving purposes."

The same authority, in discussing the properties to be considered in the purchase of asphalt paving sand, considers several of the many properties in detail. He says:

"*The composition*[1] of a sand, as long as the grains are hard, cannot seriously affect its availability in an asphalt-surface mixture or be a cause of defects in it. Soft-grained sand should be rejected when this is possible. ****The lake sands often contain considerable carbonates in the form of shells, and a small amount is found in almost all. ****Their presence has no injurious influence on the sand as far as its use in asphalt surface mixture is concerned. ***A clean sand is in any case probably more desirable, although satisfactory results have been obtained with many loamy ones. ***Organic matter in the shape of vegetable debris is sometimes found in sand. It is usually removed in screening. ***If this is not possible and the amount remaining is excessive the sand should be rejected."

"*The shape of the grains*[2] of a sand has a marked influence, when combined with their size and grading, upon the character of the asphalt surface mixture made with them. ****Mixtures made with round-grained sands are of course less stable***than those made with sharp sand, since round particles move much more readily over one another than sharp ones; but, on the other hand, with plenty of filler this tendency can be neutralized, while the round-grained sands can be packed much more readily and closely and with smaller voids and the resulting surface can, in this way, be made denser."

"*Surface of Sand.*[3] The different kinds of surfaces have quite differently toward asphalt cement. The porous limestone surfaces absorb it, and it, of course, adheres very firmly. To the quartz surfaces the bitumen adheres, in most cases, well."

"*The size of sand grains*[4] in an asphalt pavement, that is to say, their average diameter, is of the greatest importance. ***In a standard sheet asphalt surface it has been found generally preferable to have no sand grains larger than 2 millimeters in diameter, passing a 10-mesh sieve made of wire .027" in diameter, or smaller than .17 millimeter, which pass a sieve of 100 meshes to the inch, made of wire .0043" in diameter."

In another place Richardson says:[5]

"Bank sands***are oftener to be obtained of that degree of fineness which has been found to be such an essential feature in our modern mixtures, that is to say, of 80-and 100-mesh size."

Describing a Kentucky asphaltic sand, he again says:[6]

"The sand grains are extremely coarse, the majority of them being of 50 and 40 mesh in size in one instance, and larger than 30 in an other. Such a sand grading alone would make this material unsuitable for use in an asphalt surface."

---

[1]Richardson, Clifford, op. cit., pp. 53-56.
[2]Op. cit., p. 57.
[3]Op. cit., pp. 57-59.
[4]Op. cit., p. 59.
[5]Op. cit., p. 46.
[6]Op. cit., p. 224.

Regarding natural asphaltic sand, the same physical properties are requisite as are demanded for artificial mixtures. Concerning the nature and amount of bituminous matter desirable, there seems not to be unanimity of opinion. Orton[1] reports that the maximum amount of bituminous matter in the Kentucky asphaltic sandstones is probably not over 10 per cent. Richardson[2] gives thirteen Kentucky analyses ranging between 4.3 per cent and 13.7 per cent, with an average of about 8 per cent. Of these Kentucky natural asphalt sand he reports:

"***That no satisfactory asphalt pavements can be constructed from any of the bituminous sands available in Kentucky for two reasons. In the first place the bitumen is a maltha which has no stability.***In the second place it is not present in sufficient amount to cement the sand-grains together satisfactorily.***It may be possible, for light traffic streets, to make an asphalt surface mixture from a Kentucky sand by the addition of some hard bitumen, ***but when this is done it would generally be found to have been a matter of economy not to have used the bituminous sand at all, but to have started with a suitable local sand and have combined this with a proper asphalt cement and a good filler."

He also cites twenty-seven Oklahoma asphalt sand analyses[3] ranging in bitumen from 1.6 per cent to 18 per cent, and averaging about 9 per cent. Of these he also says:

"They contain too little bitumen and this bitumen is not sufficiently asphaltic in character."

The above quotations give a fair idea of the qualities presented by Richardson, who is considered an authority on the subject.

Snider[4] gives the following table of analyses of Oklahoma asphalt sands.

Analyses of rock asphalt pavement samples.

Total bitumen.	Asphaltine.	Petrolene.
8.53	22.40	77.60
7.85	21.19	78.81
8.05	21.90	78.10
9.97	22.45	77.55
10.10	27.35	72.65
9.80	29.39	70.61
9.95	25.21	74.79

[1]Orton, Edward, Report on the occurrence of petroleum, natural gas and asphalt rock in western Kentucky; Kentucky Geol. Survey for 1888 and 1889, p. 211, 1891.

[2]Richardson, Clifford, op. cit., pp. 221-230.

[3]Op. cit., pp. 230-240.

[4]Snider, L. C., Rock asphalts of Oklahoma and their use in paving; Oklahoma Geol. Survey, Circular No. 5, p. 18, 1913.

He cites numerous cases where this natural asphalt rock has been used with marked success in street work, even for heavy traffic. This is in direct contradiction of the conclusions of Richardson.

Hutchison[1] also calls attention to the fact that natural asphalt pavements in many Oklahoma cities compare more than favorably with those made from artificial mixtures.

It must be said, in the final summing up, that results of actual use should be given greater weight than chemical and mechanical analyses.

GRAVEL FOR ROADS.[2]

Gravel is used widely for surfacing roads in this State. Unfortunately little or no data are available regarding the amount of gravel thus used, because a large part of it is hauled by farmers directly from the streams and no record is ever kept.

The following qualities are to be desired in a good gravel for surfacing roads:

1. The fragments should be hard enough so that they will not grind up under the impact of traffic. Among the most resistant rocks are trap, granite and related rocks, and chert. Much the greater part of the gravel in Missouri is of chert, and so far as hardness is concerned, is a suitable road material. In southeast Missouri, in the vicinity of the St. Francois Mountains, gravels are found consisting of granite, trap, and porphyry pebbles, all of which are sufficiently hard. In northwest Missouri glacial gravels are found. These contain many badly decayed granite and other igneous pebbles, and are practically the only gravels in the State which are likely to go to pieces unduly when used on roads.

2. The gravel should consist of different sizes in the proper proportions to constitute a graded aggregate. Stones larger than 1 to 2 inches should not be used, and if present in the gravel, should be removed by screening, as they have a tendency to work to the surface under the action of the frost. The aggregate should be graded as to size, so that the binder will occupy as small a proportion of the mass as possible, it being the least able to resist wear. Where a large amount of gravel road is

[1]Hutchison, L. L., Preliminary report on the rock asphalt, asphaltite, petroleum, and natural gas in Oklahoma, Oklahoma Geol. Survey, Bull. No. 2, pp. 90-93, 1911.

[2]Baker, I. O., A treatise on roads and pavements, 2d ed., pp. 146-176, 1914.

Buckley, E. R., Public roads, Missouri Bureau of Geol. and Mines, vol. 5, 2d ser., pp. 19 and 88, 1907.

to be built, it may become desirable to screen the gravel into several sizes and recombine, as in concrete work, in order to give the minimum of voids.

3. It is desirable that the gravel should be sharp, since a sharp aggregate bonds more thoroughly and is less mobile. Crushed rock, because of its greater angularity, is even better suited than gravel to road surfacing. Little of the Missouri stream or bank gravel can be said to be really angular. "Hardpan" residual soils high in flint are sometimes used. These constitute the so-called upland gravels and are usually angular, but are, as a rule, too high in clay to make good roads. Occasional deposits are known which are valuable road metal. A pit of this type is worked locally at Daisy in Cape Girardeau County, and a very large deposit near Wittenberg in Perry County is being used for railroad ballast. Other scattered deposits are reported, and it is probable that the material is more widespread than present information indicates, especially where the region is underlain by certain very cherty limestones of probable Devonian age, or by the Boone or Burlington-Keokuk of Mississippian age. These formations, consisting largely of limestone with heavily interbedded chert members, leach and slump, leaving sharply angular, residual cherts. Older limestone formations also leave occasional deposits of residual flint and clay suitable for road surfacing.

4. The most important property of a good gravel for road metal is the facility with which it packs or binds. A clean, worn stream gravel spread over the surface of the road makes a very uninviting driveway unless it is mixed with some binder. To secure the best bond, the pebbles should be in contact at the greatest possible number of points, a condition fulfilled by the graded aggregate. This insures the best bond with the minimum of binder. For ordinary gravel roads, the most common binder is clay. It is not wholly satisfactory, however, because excess of moisture softens it excessively, and long drought causes it to crack up and break away from the pebbles, after which it powders rapidly and blows away, yielding much dust. In spite of its defects, it is the most available binding material and will long continue to be used on rural roads. The best practice goes to show that from 10 to 20 per cent of clay is the proper proportion. Less than that is scarcely sufficient, and more causes a road that does not drain well, and becomes sticky when wet.

The creek flint gravels of the Ozark region and of northeast

Missouri, which make up most of the deposits of gravel in the State, are much too clean and worn to make good road surfacing without adding a binder. Nevertheless, many miles of Ozark roads have in the past been surfaced with such gravels, forming a rolling, shifting driveway into which the wheels of vehicles cut deeply. It is now coming more generally to be understood that a binder should be added, and for this clay is widely used. These gravels, as they wear, have little cementing power; in other words, the dust from their wear has little value in cementing the pebbles together.

The residual hardpan flint gravels already mentioned usually have sufficient clay to be self-cementing; in fact, the greatest objection to them in general is that they contain an excess of clay.

In the northwest counties of the State, the glacial outwash gravels have been rather generally used for road purposes. They contain granite, flint, limestone and other pebbles, many of which have considerable cementing power. The gravel also contains a small quantity of clay which acts as a binder. In spite of the fact that many of the pebbles are partially decomposed and on this account easily go to pieces, the material is widely used, apparently with fair results, for road surfacing.

Near Pacific in Franklin County, near Commerce and Benton in Scott County, near Dexter in Stoddard County, and near Campbell in Dunklin County, there are deposits usually referred to the Lafayette formation, consisting of a peculiar, very compact gravel, with a highly ferruginous clay matrix. The pebbles vary in size, rarely being over two inches and averaging considerably smaller. Large patches of the material show no grains larger than ¼ to ½-inch. The pebbles are mostly flint and vein quartz. The matrix of ferruginous clay is very firm, and the pit walls stand vertical or overhanging. The material packs well and gives a very satisfactory wearing surface.

The best gravel roads, gravel walks, and park drives are commonly surfaced with the grade of gravel usually known as torpedo. Torpedo gravel produced by different plants varies somewhat in size, the average grain being about 1-8 to ¼-inch in diameter.

No regular tests of hardness, toughness, cementing power, resistance to abrasion, resistance to impact, absorption, or other properties of road metal have been made for this report.

GRAVEL FOR RAILROAD BALLAST.

Although cinders, clay, burnt gumbo, chats, and crushed rock are also used for railroad ballast in the State, this paper will deal only with sand, gravel, and other natural products. During the year 1913, 10.3 per cent of the tonnage and 3.5 per cent of the value of the output of sand and gravel in the State was used for railroad ballast. It was the cheapest grade of gravel handled, averaging 9.1 cents per ton.

While there is considerable dispute as to the comparative value of gravel and crushed rock, the former, where, it is properly handled, is coming to be very generally regarded as an excellent ballast material.

In general, gravels to give the best results when used as ballast should be angular, for angularity causes the gravel to bind better, to roll less, and to make the road bed less mobile. Unfortunately very little angular gravel is found in the State.

Graded gravel is best for ballast, because there is a smaller proportion of voids, the individual pebbles are in contact at a larger number of points, and the mass is less mobile. For these reasons, a certain amount of sand should be present in a gravel ballast.

Clay or loam, technically known as dust, is undesirable in gravel for railroad ballast, because it gives a soil for the growth of weeds on the track; disturbs drainage, with resultant decay of ties; and makes a dusty right-of-way.

The report of the Committee on Ballasting of the American Railway Engineering and Maintenance of Way Association makes the following statements and recommendations:[1]

"1. Gravel with much over 3 per cent of dust does not drain freely; with less than that amount drainage is good.

2. Gravel with less than 2 per cent dust makes a fairly dustless road bed.

3. Pebbles should not exceed 2 inches in size. Larger pebbles should be crushed and returned to the ballast.

4. Less than 20 per cent sand permits pebbles to shift, under load, and over 50 per cent prevents ballast from becoming firm.

5. The Committee recommends for

Class "A" roads, 10 parts gravel and 3 parts sand. Bank gravel with over 2 per cent dust or 40 per cent sand should be washed and screened.

Class "B" roads. 10 parts of gravel and 6 parts sand. Bank gravel with over 3 per cent dust or 60 per cent sand should be screened or washed.

Class "C" roads. 10 parts gravel and 10 parts sand. Any gravel not over 6 per cent dust may be used."

[1]Engineering News, April 15, 1909.

The foregoing classes refer to the amount of traffic handled, and are defined in the manual of the American Railway Engineers' Association.

In many states, plants are being installed for the washing and screening of ballast. From one of these the following data are presented, which may be of interest.[1]

	Cents	
Loading rough gravel	8.95	per yard
Washing gravel	11.34	" "
Hauling	11.11	" "
Placing in track	26.15	" "
Total	57.55	" "

From this bar, about 10 per cent of the gross output was sold as commercial sand, a by-product from the screening and washing of the gravel. This was a resource to the company both from its sale and its haulage.

There are practically no places in the State where washed and screened ballast is now handled. The plant at Hannibal and the Meramec River plants produce some washed ballast as a by-product from the production of commercial sand and gravel, but the amount is small. Most ballast goes to the track as dredged. The extreme variation in composition of stream gravel from the Ozark and northeast Missouri areas would demand screening to guarantee the right proportions of sand and pebbles for the best grade of product. The glacial gravels of the northwest part of the State are high in dust, and for the best results, would probably need washing. Near Wittenberg in Perry County, a large deposit of residual angular chert has resulted from the leaching of a highly cherty limestone. This deposit, which in its nature approaches tripoli, is used extensively for ballast and is said to be satisfactory.

FOUNDRY SAND.

During the year 1913 moulding sand made up 3.2 per cent of the weight and 5.8 per cent of the value of the output of sand and gravel in the State. The price for that year averaged $.482 per ton.

The following description of the properties of moulding sands is condensed directly from the detailed report by Ries and Rosen.[2]

[1]Engineering and Contracting, vol. XXXVII, p. 341, Mar. 27, 1912.
[2]Ann. Rept., Michigan Geol. Survey, 1907, passim.

Under the term foundry sand there is included (a) sands for making the mould itself into which the metal is poured, and (b) core sand for the cores which fill the hollow spaces in the casting. In general, moulding sands are finer and more loamy than core sands, the latter being low in natural bond. For large castings, a coarse porous sand is needed to allow of proper steam escape, while the smooth surface of smaller and finer castings demands a finer sand. For steel castings a very refractory sand is needed to resist the necessarily high temperature, and sands lower than 97 per cent of silica are seldom used. For other castings, 70 to 80 per cent of silica is usually sufficient.

Briefly stated, the requisites of a good foundry sand are cohesiveness, refractoriness, suitable texture, porosity and permeability, and durability. These properties may well be examined more closely.

1. *Cohesiveness.* The sand, when slightly moistened, or tempered as it is called, must cohere sufficiently to form a mould. This property is due to the presence of a small amount of clay in the sand. Core sands in which the binder must be destroyed by the heating process, in order that the core may be easily removed from the hollow space, usually demands an artificial binder, that will burn out, leaving the sand loose, after the casting is complete. Neither chemical nor mechanical analyses seem to throw much light on this property. Some low alumina sands are very cohesive, while others with a much higher content of alumina are only slightly cohesive.

2. *Refractoriness.* Sands should be sufficiently refractory that upon casting, the surface of the mould is not fused. This is imperative, since for the escape of the steam formed, the sand must remain porous, and fusion destroys this porosity. For steel casting, where extremely high temperatures are encountered, a highly refractory sand is demanded. Since silica is the commonest refractory substance, very pure silica sands are used, running 97 per cent or more. For casting iron and other metals, where the temperatures are lower, the sands need not be so refractory, and lower silica content is allowable, down to 80 or even 70 per cent. A very high percentage of fines usually indicates a less refractory sand, since most of the clay particles are in the fines, and the clay carries the fluxing substances. The fluxes are iron oxide, lime, magnesia, and the alkalies. Lime by itself is highly refractory, and is sometimes used as a fire-wall lining between the metal and the sand. This does not, however,

invalidate the conclusion that lime fluxes silica, and hence lowers the refractoriness of moulding sands, when intimately mixed with them.

Although chemical analysis is by no means a sure test of refractoriness, a very high silica content (97 per cent or more) almost certainly indicates a very refractory sand, while high iron, lime, magnesia, or alkalies indicates a sand whose refractoriness is low. No exact data are available to show relation of quantity of fluxes to temperature of fusion. The relation does not appear to be a direct one. Other factors being equal, a fine-grained sand is less refractory than a coarse one.

3. *Texture.* This is highly important in a moulding sand, because it effects closely the permeability and determines the grade of casting for which sand is suited. There are several methods for determining the texture, all of them based on a separation of the sand into various sizes. Since Missouri reports but few deposits of moulding sand, it was not deemed sufficiently important to warrant an elaborate series of tests. Tests were made with a series of screens varying as follows: 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 150, 200. The sizes of opening are given on p. 12, and the results of these tests will be given under the discussion of sands by formations and districts.

4. *Porosity and permeability.* These properties, while closely related, are quite distinct. Porosity is the percentage of empty space or voids between the grains. Permeability is the property by virtue of which liquids or gases filter through it. Large amount of pore space, if the pores are individually very small, may yield a very slight permeability, while a relatively low porosity, if the pores are large and continuous, may give a highly permeable sand.

Permeability is to be desired, since it is necessary to allow the escape of steam during pouring; otherwise, the steam forms blow holes and damages the casting. Permeability is sometimes determined by the aspirator, but no such tests were made for Missouri sands. Porosity alone cannot be used as an indication of permeability, though coarse texture and high porosity combined usually indicate it to a fair degree. A sand, the refractoriness of which is low even though originally permeable, may fuse and close the pores.

5. *Durability.* Perhaps owing to the dehydrating of clay particles, sand burns out, with consequent loss of adhesiveness.

Fusion may also cause adhesion of grains and coarsening of texture. Some sands lose their value after being once used, while others can be used several times. Durability is a property which can be determined only by use.

On Missouri moulding sands, the following tests were made: chemical analyses for silica, alumina, iron oxide, lime, magnesia, and alkalies; screen tests with the screens as shown on page 11; specific gravity; and porosity. Many users claim that chemical analyses are no indication whatever of the value of a sand for foundry purposes, but it is customary to have analyses made.

The following are specifications for steel moulding sand used on the Isthmus by the Panama Canal Commission.[1]

"Sand, silica, to be sharp, free from loam and other organic matter, and suitable for steel castings, shall show the following upon analysis":

Analysis of sand suited for steel casting.

"SiO_2	95-100 per cent.
Fe_2O_3	Under 1 per cent.
CaO	Under 1 per cent.
MgO	Under 1 per cent."

H. E. Field,[2] gives the following characterization of a good moulding sand for ordinary castings:

"It is very necessary that a sand be chosen with a low percentage of strong bond rather than a large percentage of weak bond.****The strength of a moulding sand determines its adaptibility for different kinds of work.**** The strength of sand depends upon three conditions: first the proportion of bond; second the strength of the bond; and third the shape of the quartz silica particles."

He gives the following as a desirable chemical composition:

Theoretical composition desirable for moulding sand.

Silica	75-85 per cent.
Alumina	7-10 per cent.
Lime below	2 per cent.
Oxides of iron below	6 per cent.
Alkalies below	½ per cent.

Several special varieties of foundry sand are defined in the following paragraphs:

Brass sand is a very fine sand for making moulds for aluminum, brass, and bronze castings. It has a strong bond, but, owing to its extreme fineness, is only slightly permeable. It must be used with great care to prevent "blowing."

[1]Stone, R. W., Sand and gravel; Mineral resources of United States for 1913, pt. 2, p. 334.

[2]Iron Trade Review, p. 19, Mar. 15, 1906.

Facing sand is a fine sand used for facing certain moulds, where a smooth finish is desired on a heavy casting which demands a mould of coarse sand. It is simply a fine grade of moulding sand, and would for lighter work be perfectly fitted for the whole mould.

French sand is a fine, open, sharp, yellow sand imported from France for brass and bronze casting.

Parting sand is a fine, non-cohesive sand, free from clay, and is used to dust the meeting faces of the parts of a mould to prevent sticking. Brick moulds are also dusted to facilitate the removal of the form from the mould.

Moulding sands are reported in Missouri from near Crystal City, at the contact of the loess with the St. Peter sandstone, and from South St. Louis, near the contact of the loess with very fine-grained terrace sands. Moulding sand for steel casting is taken largely from the St. Peter, its high silica content rendering it extremely refractory. For this use, the St. Peter must have an artificial binder added, such as molasses-water, flour, or ground clay. The St. Peter is also used for core sand, as is also the finer-grained sand from the Missouri and the Mississippi. These must also have artificial binder added. There are no data as to the refractoriness of the Mississippi and Missouri river sands, but their continued use indicates that for ordinary core work they have been found reasonably satisfactory.

ENGINE SAND.

The engine sand output for the last four years has averaged about one per cent of weight and of value of the total sand and gravel output of the State. During the same period, the price has averaged almost 20 cents per ton. This sand is used in railroad engines to sand tracks and to increase traction on slippery rails.

Owing to vegetation on the railroad tracks, the consumption of this sand is larger in the spring and early summer than in other seasons. In winter slippery tracks would naturally cause heavy demand, but the feeding pipes clog with snow at the bottom and prevent the ready use of sand. According to Condra,[1] a good engine sand should have the characteristics of dryness, coarseness, sharpness, and hardness. It must be dry. Since it is carried in the sand dome of the engine, and fed to the rails

[1]Condra, G. E., Sand and gravel resources and industries of Nebraska, Nebraska Geol. Survey, vol. 3, pt. 1, pp. 186-190, 1908.

through tubes, the sand must be thoroughly dry to prevent clogging in the feeding tubes. Practically never is sand secured sufficiently dry for the purpose. The process of drying has already been described. (p. 43.) The sand should be sufficiently coarse to remain on the rail in a moderately strong wind, but it should be free from sticks or coarse pebbles that will clog the feeders. Coarse material is usually screened out. Specifications often call for a sharp sand, but as angular fragments are produced by crushing as soon as the wheel passes over the sand, it is quite probable that sharpness is not particularly essential. The grains should consist of some material sufficiently hard not to be entirely crushed to a powder on being used. For that reason, quartz or flint sands are desirable. If properly screened and dried, almost any of the commercial river sands from the Missouri, Mississippi, or Ozark streams should be suitable for this purpose.

FILTER SAND AND GRAVEL.

The proper filtration of public water supplies is receiving more and more attention. Up to 1913, no plant in this State supplied specially prepared filter material. During the latter part of that year, however, a plant was established at Crystal City for the washing and screening of Mississippi River sand, and a plant at Pacific on the Meramec arranged to handle the coarser filter gravels.

The following specifications from advance chapter 19, Mineral Resources of the United States for 1913, pt. 11, pp. 336-337,[1] show the ordinary run of specifications for filtration plants.

The specifications for the filtration plant at Washington, D. C., which called for proposals for furnishing 140,200 cubic yards of filter sand and 42,300 cubic yards of filter gravel, were as follows:

"*Filter gravel.*—On the floor of the filters and surrounding the underdrains shall be placed gravel or broken stone having a maximum depth of 1 foot. Instructions will be given by the Engineer officer in charge as to the exact arrangement and positions of the various layers when the stone commences to be received upon the ground, but the arrangement will be approximately as follows: The lower 7 inches shall consist of broken stone or gravel which will remain upon a screen with a mesh of 1 inch, and which has but very few stones over 2 inches in diameter. Above this shall be placed 2½ inches of broken stone or gravel which has passed a screen with a mesh of 1 inch, and which remains upon a screen with a clear mesh of 3-8 inch. Above this shall be placed 2½ inches of broken stone or gravel, which has passed a

[1] Stone, R. W.

screen with a mesh of 3-8 inch, and which is coarser than the ordinary sand, and entirely free from fine material.

"The material for all of the layers may be broken trap rock or granite screened to the proper sizes, or gravel screened from sand and gravel banks of a sandy nature. Gravel screened from hardpan or clayey material can not be sufficiently cleaned. The gravel shall not contain more than a very small amount of shale or limestone. The gravel shall be washed entirely free from fine material, so that water passing through it or agitated in contact with it will remain substantially clean.

"*Filter sand.*—The filter sand shall be clean river, beach, or bank sand, with either sharp or rounded grains. It shall be entirely free from clay, dust, or organic impurities and shall, if necessary, be washed to remove such materials from it. The grains shall, all of them, be of hard material which will not disintegrate and shall be of the following diameters: Not more than one-half of 1 per cent by weight shall be less 0.13 millimeter; not more than 8 per cent less than 0.26 millimeter. At least 7 per cent by weight shall be less than 0.34 millimeter, at least 70 per cent less than 0.83 and at least 90 per cent less than 2.1 millimeters. No particle shall be more than 5 millimeters in diameter, and the sand shall be passed through screens or sieves of such mesh as to stop all such particles, and no screen or sieve shall be used containing at any point holes or passages allowing grains larger than the above to pass. The diameters of the sand grains will be computed as the diameters of spheres of equal volumes. The sand shall not contain more than 2 per cent by weight of lime and magnesia taken together and calculated as carbonates. In all other respects the sand shall be of a quality satisfactory to the Engineer officer in charge.

"The filter sand shall be placed in the filters in three layers, each layer to be about 1 foot thick, and the sand shall not be dropped from a height into final position or otherwise unduly compacted. The first two layers may be filled in to only approximate depths and the surfaces need not be smoothed. The final layer shall be brought to a true and even grade, and the surface left smooth and uniform."

The specifications for the plants at Springfield, Mass., and Toronto, are practically identical, as follows:

"The filter sand shall be clean sand, with either sharp or rounded grains. It shall be entirely free from clay, dust, or organic impurities, and shall, if necessary, be washed to remove such materials from it. The grains shall, all of them, be of hard material which will not disintegrate. The effective size shall not be less than 0.25 millimeter nor more than 0.35 millimeter. The uniformity coefficient shall not be more than 3.0. The sand shall be free from dust and shall not contain more than 1 per cent finer than 0.13 millimeter, and shall be entirely free from particles over 5 millimeters in diameter. The sand shall not contain more than 2 per cent by weight of lime and magnesia taken together as carbonates. In all other respects the sand shall be of a quality satisfactory to the engineer."

The plant at Pacific produces the following sizes of screened and washed gravel for the filter bed:

Sizes of filter-bed gravel.

Coarse gravel through 1 3-4 inch on 1¼ inch mesh.
Medium gravel through 1-inch on 3-4-inch mesh.
Fine gravel through 3-8-inch on 3-16-inch mesh.

The sand produced at the Crystal City plant must conform to the following specifications furnished by the Company from the St. Louis office:

"The sand shall be composed of hard and durable grains, either sharp or rounded, substantially free from clay, loam, dust, or organic matter and flat particles.

"When the sand, crushed and powdered, is digested for twenty-four hours in strong, warm hydrochloric acid, without stirring, at least 95 per cent shall remain insoluble. The sand shall not contain more than two per cent of calcium and magnesium, taken together, and calculated as calcium carbonate ($CaCO_3$).

"The sand shall have an effective size of not less than 0.40 nor more than 0.50 of a millimeter and a uniformity coefficient not greater than 1.65. Not more than one-fourth of one per cent shall be finer than 0.25 of a millimeter. At least 95 per cent shall be finer than 1.2 millimeters. The diameters of sand grains shall be computed as the diameters of spheres of equal volumes, and all percentages shall be calculated by weight."

GLASS SAND.

Glass sand includes, properly speaking, only the sand used in the batch. Technically, it is known as melting sand. The sand used for grinding and polishing is listed under the name of grinding and polishing sand. During the year 1914, glass sand made up 4.5 per cent of the weight, and 11.0 per cent of the value of the total output of sand and gravel in the State. During the same year, it averaged 70.2 cents per ton.

The essential properties of a good glass sand are somewhat variously given by different authorities. Burchard[1] gives the following discussion of the requirements of glass sand:

"Sand is therefore the major constituent of glass, constituting from 52 to 65 per cent of the mass of the original mixture, or from 60 to 75 per cent of the finished product after melting has driven off carbon dioxide, sulphur dioxide, and other volatile materials. To the sand is due the absence of color (according to its purity), the transparency, brilliancy, and hardness of glass. In other words, the quality of the glass depends largely on the quality of the sand. For the finest flint ware, such as that used for optical and cut glass, 'water whiteness,' absolute transparency, great brilliance, and uniform density are required, and only the purest sand can be employed, since slight impurities, especially small quantities of iron, tend to destroy these effects. For plate and window glass, which are commonly pale green, absolute purity is not so essential, but generally the sand should not carry more than 0.2 per cent of ferric oxide. Green and amber glass for bottles, jars, and rough structural work can be made from sand relatively high in impurities. An excess of the chief impurity, iron, is usually avoided in the quarries by a careful selection of the whitest sand, although the whitest sand is not invariably the purest. Repeated washing tends to remove the iron. Magnetic separators also have been resorted to, especially when the iron is present in the form of magnetite.

[1]Burchard, E. F., Glass sand, other sand, and gravel; Mineral Resources of the United States for 1911, pt. 2, pp. 594-5.

Clay materials are objectionable because they cloud the glass. Washing helps to remove them, since they occur usually in a very finely divided state. Magnesia, which is more apt to be introduced into glass materials through limestone than through sand, is troublesome because it renders the batch less fusible. If the sand is derived from indurated sandstone the latter should be friable or easily crushed. In examining sand in order to ascertain its value for glass making, inspection with a magnifying glass is the best preliminary test. The following points should be observed: The sand should be nearly white in color; it should be of medium fineness (passing a 20 to 50 mesh horizontal sieve); the grains should be uniform in size, even, and angular, or, less preferably, they may be rounded. A simple chemical test may be employed by heating the sand in a dilute acid. Effervescence indicates the presence of lime; loss of color shows the presence of clay impurities. Iron in the most minute quantity may be detected by dissolving sand in hydrofluoric acid and adding potassium ferrocyanide, which produces a blue precipitate if iron is present. Complete quantitative analyses as well as a furnace test should be made as a final determination of the character of a prospective glass sand. The impression has long prevailed, especially among writers on the subject of glass making, that round-grained sands are at a decided disadvantage in comparison with the sharp, angular variety. Practice seems to disagree with this idea, at least in the case of the Mississippi Valley plants, where smooth, rounded sand is successfully used for all ordinary varieties of glass and for some fine flint ware. As a rule, no very close check is kept on materials by manufacturers of the ordinary commercial grades of glass. Results are watched with care, however, and experience with certain materials usually determines their use or rejection. Sand uniformly finer than one-sixtieth inch is said to 'burn out' in the batch and not to produce as much glass per unit of weight as does coarser sand. In a mixture of coarse and fine sand the finer sand is liable to settle to the bottom of the batch, thus preventing an even mixture of the materials and producing in consequence a glass uneven in texture."

Buttram[1] gives the following properties of glass sands:

"*Shape of grains.*—The prevailing opinion among glass sand experts has been that the sand grains should be sharp and angular, never rounded and smooth. The contention has been that the rounded and smooth grains do not leave as many interstices through which the heat can pass as do the sharp angular grains. For this reason it has been maintained that the round grains have a tendency to settle to the bottom of the batch in the melting pot and prevent an even flux, producing an unevenness and irregular quality in the glass. Some of our prominent glass men of today, however, are of the opinion that more attention has been given to the shape of the grain than is warranted, and they contend that it is not an important factor and that any good silica sand, if of a proper degree of fineness, will become liquified very readily. This conclusion has been reached because of the fact that several prominent glass plants in the Mississippi Valley are successfully making both the ordinary grades of glass and the fine flint wares from the sand composed entirely of rounded grains.****

"*Size of Grains.*—There are also varied opinions as to the most desirable size of the grains. There are those who contend that the size and shape of the grains have nothing to do with the quality of the glass, but that a small grain will melt more quickly and consequently require less fuel, as the flux

[1]Buttram, Frank, The glass sands of Oklahoma, Oklahoma Geol. Survey, Bull. 10, pp. 16-17, and 10-11, 1913.

can act only on the surface of the grain. But the prevailing sentiment is that to produce the best results the grain should not be larger than 30 mesh nor smaller than 120 mesh. If the sand is pure, however, the size of the grains may have a somewhat wider range and still good results be obtained, so long as the grains are comparatively uniform in size.

"The fine sand is said by some to 'burn out' in the batch and not produce as much glass per unit as does coarser sand. The grains larger than 30 mesh on the other hand are more difficult to fuse. This lowers the amount of sand each furnace can melt per day and consequently increases cost of production. As already noted, in a mixture of coarse and fine sand the finer is liable to settle to the bottom of the batch, thus preventing an even mixture of the materials and producing in consequence a glass uneven in texture.

"*Silica.*—Sand is composed principally of silica (SiO_2), and the purest glass sands contain practically 100 per cent of this oxide, with only traces of impurities. From this maximum all gradations in composition may be found down to sands containing such large percentages of impurities that they cease to be sands. The best grades of glass sand obtained from the Illinois and Missouri fields are reported to contain from 99 to 99.9 per cent silica, while the poorest grades sometimes run as low as 90 per cent silica.

"*Impurities.*—The most harmful impurities found in sand are iron, clay, magnesia, and organic compounds. Iron is a strong colorizing agent imparting to the glass a green, yellow, or red color, which varies with the amount and the degree of oxidation of the iron. Aluminous substances (principally clay) lessen the transparency of the glass and for the higher grades their presence in excessive amounts must be avoided. The presence of magnesia raises the fusion point of the batch and thus more fuel must be used to melt the charge. Organic matter is a strong colorizing agent and produces a dark amber color.

"To neutralize the colorizing effects of these impurities upon glass, decolorizing agents are sometimes used. The principal decolorizing agents are manganese, arsenic, antimony, potassium nitrate, nickel oxide, and cobalt oxide. These ingredients are used in small quantities, since in large quantities they become colorizers instead of decolorizers.

"The percentage of impurities allowable in glass sand depends upon the grade and character of glass desired. For the finest flint ware, such as optical and cut glass, only the purest sand can be utilized, perfect transparency, great brilliancy, and uniform density of product being required. For manufacture of this ware the sand should not carry more than .05 per cent of iron (ferric oxide, Fe_2O_3), or .1 per cent of alumina (Al_2O_3). For the manufacture of plate and window glass, however, which are commonly a pale green, and which do not require as pure a grade of sand, .2 per cent each of iron and alumina is not injurious; and, in some cases, as when decolorizing agents are used, the sand usually contains .3 to .4 per cent iron and .6 to .7 per cent alumina. Some grades of English plate and window glass contain as much as 1.92 per cent iron and 2.68 per cent alumina. The French mechanically pressed plate glass averages about .14 per cent iron and 1.27 per cent alumina, and the English .49 per cent iron and .7 per cent alumina. Lead glass contains as high as 1.93 per cent each of iron and alumina, and lime glass, as high as 5 per cent iron and 6.22 per cent alumina. In the better grades of bottle glass the iron averages about .65 per cent and alumina about 2.2 per cent. Since sand forms only 50 to 80 per cent of the batch, the percentage of iron and alumina may be still higher than these figures."

It will be noted that the latter authority gives a much higher allowable percentage of iron than the former. In order

to determine the actual practice in some large factory, the writer communicated with Mr. F. Gelsthorp, Chief Chemist of the Pittsburgh Plate Glass Company, Creighton, Pa. Mr. Gelsthorp very kindly sent us the following statement of the practice in their own plants:

"A good plate glass sand should not contain more than 0.05% of either Fe_2O_3 or Al_2O_3; but, we consider the limit as .10% Fe_2O_3 and .50% Al_2O_3. Sand containing above .10% Fe_2O_3 produces a plate glass which is objected to on account of the color which is easily seen in the reflection of anything white in a mirror made from such glass. Window glass manufacturers are able to use the inferior sands, which may contain .20% Fe_2O_3 and as much as 1.00% Al_2O_3.

"Regarding the clay, this is usually removed from sands intended for glass melting by washing, which also usually reduces the iron content. Therefore, before a proper opinion can be passed regarding the suitability of a sand for glass melting purposes, the analysis should be made of the material after it has been washed free from clay, etc. Apparently worthless sands are sometimes lowered in this way so much in iron as to pass into a class very suitable for glass melting.

"Some glass manufacturers add decolorizers to the batch to mask the green color due to iron, but this is not practical in plate glass manufacture.

"The commoner glass for bottles can be made from very inferior sands, while the manufacturers of crystal glass, ornamental, blown and pressed glass ware require the very purest sands containing only traces of iron."

While it is rather generally stated that magnesia renders the batch less fusible and is an undesirable impurity, no quantitative data have been found that show the percentage above which magnesia becomes particularly harmful.

The following conditions outlined by Burchard[1] determine largely the value of any given glass sand deposit:

"Glass sand in situ possesses relatively little intrinsic value. The market value is due to the labor cost of extraction and preparation.

"The factors on which a deposit of sand depends for its possible value for making glass are (1) chemical purity, (2) physical character, (3) quantity available, (4) location with respect to fuel supplies, (5) conditions of quarrying or mining, (6) location with respect to transportation routes, and (7) location with respect to markets. * * * *

"A deposit so thin as 20 feet should have an areal extent of at least 20 acres of good sand in sight to warrant the erection of a mill and trackage. Most deposits are thicker than 20 feet, but it would be safer to have a much higher ratio between areal extent and thickness than the minimum given. Where ledges of sand require stripping of overlying limestone, the limestone may in certain cases be of such purity that it also could be used for glass making. If this is not the case, other uses should be sought for it as a by-product. In regard to fuel, every plant turning out glass sand in quantity sufficient to net a profit must be equipped with power for moving the sand and drying it, and in most cases with equipment for cleaning it as well. The margin of profit is at present so low that the cost of preparation can not reasonably stand freight charges on coal for more than 50 miles. Natural gas would

[1]Burchard, E. F., glass sand, other sand, and gravel; Mineral Resources of the United States for 1911, pt. 2, p. 636.

be a suitable fuel, especially in the operation of rotary driers. In respect to transportation routes, the general principle 'the more available the better' is applicable. Aside from the necessity of securing fair and uniform freight rates experience has shown, especially where the dependence is on only one railroad for transportation, that shortness of cars at certain seasons may seriously handicap a plant in its shipments and lead to cancellation of many orders. In respect to markets, it must be considered that sand is for its value one of the bulkiest products, and therefore one whose cost to the consumer is greatly influenced by distance. At the same time the question of permanence of these markets must be considered.

"Some of the large sand properties, together with their mills, represent an outlay of $75,000 to $100,000, a sum that requires good business judgment for its investment and subsequent careful management in order to keep it paying adequate interest. Strong competition in the Middle States has forced prices down very low at present, and competition in the form of the small producer who leases a sand bank and works out by hand and team all the choice sand within convenient distance and then abandons the quarry, having figured only daily wages to himself as profit, has resulted in some embarrassment to the larger companies."

At the present time the only production of glass sand from Missouri comes from the St. Peter sandstone belt, but it is possible that the Roubidoux formation may at places yield sands sufficiently pure for glass manufacture. For a discussion of the value of these sands for glass making, see the sections on the St. Peter and the Roubidoux formations.

GRINDING AND POLISHING SAND.

This grade of sand, including that used in grinding and polishing plate glass, in sawing stone, in sand blast work, etc., constituted, during the year 1913, 3 per cent of the weight, and 5.8 per cent of the value of the total sand and gravel output of Missouri. The average price per ton during that year was 51.1 cents.

For polishing glass a very hard sand is necessary, from which all coarse particles have been removed by screening. At those plants which wash their melting sand, the washings or slimes are usually run into the grinding sand. The latter is then screened to remove any large fragments that might scratch the surface of the glass. Quartz sand is used exclusively, the total production coming from the St. Peter glass sand formation.

STONE SAWER'S SAND.

A little sand for stone-sawing purposes is secured in the State. This use demands a sand that is unusually hard and sharp. The St. Peter sand is sufficiently hard, but at most places has not the requisite degree of sharpness. At a few

places, however, certain layers of the St. Peter show marked recrystallization of the quartz grains, and these layers are selected in at least one quarry near Pacific and shipped as stone-sawing sand. It is believed that the Roubidoux formation, which shows a greater degree of recrystallization, might yield good sand for this purpose.

SAND FOR SAND-BLAST WORK.

No production of sand for sand-blast work has been reported from this State. For this purpose the sand should be moderately coarse, hard, and preferably sharp. The grade of St. Peter sand shipped for stone-sawing should be satisfactory, as should also the more recrystallized portions of the Roubidoux. Many of the flint sands from Ozark streams are reasonably sharp, and should, on proper screening, be suitable for sand-blast.

FIRE AND FURNACE SAND.

Fire sand and furnace sand are synonymous terms. This grade of material has made up for the past four years less than one per cent of either weight or value of the output in the State of sand and gravel, and has averaged from 45.9 to 31.8 cents per ton during that time. It is used with either lime or fire clay binder, for lining and patching furnaces, cupolas, converters, and ladles to contain molten metal. It is used also for runners for making pig iron castings.

For the better classes of work a very pure silica sand, in which the amount of fluxing matter runs low, is used. No quantitative data are at hand, but it is to be assumed that it should at least be as refractory as a good grade of steel sand. Data shown on page 76 for steels and show the United States specifications as follows:

Composition of average steel sand.

SiO_2	95 to 100 per cent
Fe_2O_3	less than one per cent
CaO	" " " " "
MgO	" " " " "

Most of the fire and furnace sand output from this State comes from the St. Peter and averages above 98 per cent silica (SiO_2) with an average of less than 0.25 per cent each of iron, lime, and magnesia. Some of it runs considerably above 99 per cent silica.

Some unwashed chert sand from Ozark streams is used for runners for pig iron casting.

BEDDING SAND.

A small quantity of sand is used for bedding stock cars. While a few dealers have mentioned the sale of a small amount of sand for this purpose, there are no data regarding the quantity or value of the product. The sand should be free from large pebbles, and sufficiently free from clay that it will drain properly and not puddle with stable moisture.

MINOR USES FOR SAND.

Other less important uses for sand are numerous. In certain localities, considerable quantities are used in sanding the surface of freshly painted fences, stations, and other buildings. The chief purpose is protection from the carving and writing usually seen in public places. Sand is also used for sand-paper. Very fine sand is used as the base of certain scouring soaps, as glaze on pottery, for strikers on match boxes, and for filler in the manufacture of paper.

CHAPTER IV.

THE DISTRIBUTION OF SAND AND GRAVEL BY GEOLOGICAL FORMATIONS AND DISTRICTS

It is difficult to divide the sand production of the state according to its uses, because sand for many different purposes may be, and frequently is, produced from a single bank or bar. It is almost as difficult to make any satisfactory separation on the basis of districts, for the boundaries of almost any districts that could be chosen would hopelessly overlap. It has consequently been decided to outline the discussion, first by geological formations, mentioning at least briefly every formation in the State that produces or is capable of producing sand or gravel, further subdividing these where it is necessary; secondly, the classification of the St. Peter sandstone will be outlined by counties and then by producing plants; thirdly, recent sands and gravels will be classified by drainage basins and then by producing plants. From most other formations, the production is not sufficiently large to demand further subdivision.

For this discussion, the following table of formations has been adopted provisionally, as representing the most recent and most detailed available information.

Table of geological formations in Missouri.

Quaternary	Glacial [Includes Aftonian (?)]		
Tertiary	Sands, clay and gravels. (Includes the Lafayette.)		
Pennsylvania	Missouri Group	Wabaunsee	Undifferentiated.
			Tarkio.
		Shawnee	Scranton.
			Howard.
			Severy.
			Topeka.
			Calhoun.
			Deer Creek.
			Tecumseh.
			Lecompton.
			Kanwaka.

- Pennsylvania
  - Missouri Group
    - Douglas
      - Oread.
      - Lawrence.
      - Iatan.
      - Weston.
    - Lansing
      - Stanton.
      - Vilas.
      - Plattsburg.
      - Lane.
    - Kansas City
      - Iola.
      - Chanute.
      - Drum.
      - Cherryvale.
      - Winterset.
      - Galesburg.
      - Bethany Falls.
      - Ladore.
      - Hertha.
  - Des Moines Group.
    - Pleasanton.
    - Henrietta
      - Pawnee.
      - Labette.
      - Fort Scott.
    - Cherokee.
- Mississippian
  - Yankeetown.
  - Renault.
  - Aux Vases.
  - Ste. Genevieve.
  - St. Louis.
  - Salem (Spergen).
  - Warsaw.
  - Keokuk. } (Includes the Boone).
  - Burlington }
  - Fern Glen.
  - Chouteau (Including the Northview).
  - Hannibal (Including the Vermicular).
  - Phelps?
  - Louisiana.
  - Grassy Creek.
- Devonian
  - Chattanooga (Possibly Kinderhook).
  - St. Lorenz.
  - Beauvais.
  - Grand Tower (Calloway?)
  - Little Saline.
  - Bailey (Lower Helderberg) (Including so-called Clear Creek?)
- Silurian
  - Bainbridge (Niagara).
  - Noix.
  - Cape Girardeau.
- Ordovician
  - Thebes (Hudson River).
  - Fernvale (Richmond).
  - Kimmswick.
  - Decorah.
  - Plattin (Trenton, Black River, or Birdseye).
  - Joachim.
  - St. Peter.
  - Everton (until recently included in St. Peter).

Cambrian	Powell.
	Cotter.
	Jefferson City.
	Roubidoux (includes Bolin sandstone).
	Gasconade (includes Gunter sandstone).
	Proctor.
	Eminence.
	Potosi.
	Doerun.
	Derby.
	Davis.
	Bonneterre.
	Lamotte.
Pre-Cambrian	Granite, etc.

PRE-CAMBRIAN.

The pre-Cambrian rocks are chiefly granites and rhyolites, cut by a few basic dikes (Archean?) with minor quantities of slate and conglomerate (Huronian?). They are chiefly limited in outcrop to the St. Francois Mountains and vicinity, with small inliers exposed near Sullivan in Franklin County, near Decaturville in Camden County, near Salem in Dent County, and at a few other places. The pre-Cambrian contains nothing which could properly be considered a commercial sand or gravel, the conglomerate having long been consolidated into rock.

Buckley[1] describes certain granite from the pre-Cambrian area of the southern part of the State;

> "As frequently decomposed to a considerable depth, furnishing what might be termed a gravel. The rock has disintegrated so as to fall into small irregular pieces, consisting chiefly of decomposing feldspar and quartz. This material is exceptionally well adapted for improving highways, and should be used more extensively than at present."

Since the material is residual from the decay of the granite, it is questionable whether or not it might not more properly be classed, together with the other residual deposits of the State, with the recent sands and gravels.

LAMOTTE SANDSTONE.

This formation, which comprises the base of the Paleozoic in Missouri, rests unconformably on the Pre-Cambrian, as a result of which it varies greatly in thickness, being entirely absent in places, and reaching a maximum thickness of about 450 feet in other localities. The base of the formation is conglomeratic and usually highly feldspathic. The mid-portion is

[1]Buckley, E. R., Public roads, Missouri Bureau of Geol. and Mines, vol. 5, 2d series, p. 20, 1907.

finer grained and purer, though shaly layers, as well as conglomeratic and feldspathic beds, occur sparingly throughout. The upper portion contains dolomite beds.

The sandstone is usually yellow or brown on weathered outcrop, though at a few points, particularly on fresh exposures, it is white or grayish white. Even the white portions are usually marked by small spots of iron stain, probably from the alteration of mica, or some other iron-bearing mineral. The rock is usually friable, though not infrequently case hardened on the surface of outcrops. It is usually well bedded and notably crossbedded.

The most extensive area of the formation is along the axis of the Farmington anticline. About 90 square miles of this area occurs in Ste. Genevieve County, but the exposure extends northwest into St. Francois County near French Village, and southward through St. Francois County into Madison County, embracing a considerable region near Mine Lamotte, from which the formation takes its name. It is brought up by faults near Caledonia in Washington County, and outcrops sparingly about the Pre-Cambrian knobs in Iron County, though in the latter vicinity it is very thin, and disappears entirely toward the south.

Only one point was studied which gives promise of being favorable for the production of glass sand. This is along the Illinois Southern Railroad in Section 32, Township 37 North, Range 7 East, about two miles east of Sprott. The sandstone exposed in the railroad cut is easily accessible and has only a light soil cover. It might be difficult to secure a water supply, but in other respects, the location is good. This sandstone is colored on the weathered surface, but is white where freshly broken. An analysis is given below.

Analysis of Lamotte sandstone.

SiO_2	99.12
Al_2O_3	0.35
Fe_2O_3	0.12
MgO	0.04
CaO	0.00
Ignition loss	0.33
Total	99.96

This sand is suited for ordinary glass, but not for the best grades of plate glass.

The following sample of the Lamotte sandstone is typical of the coarser conglomeratic beds:

Sample 217. This is a conglomerate sample from a two-

foot bed of grit in the sandstone, taken along the West Fork of Jonca Creek in Ste. Genevieve County. The pebbles are chiefly vein quartz with some flint, the largest of which are about ½-inch in diameter. The conglomerate is friable enough to be easily crushed in the fingers. Eighty-one per cent passed the ¼-inch screen. The specific gravity of these screenings is 2.60, the voids 37.3 per cent, the weight per cubic foot 101.88 lb., and the weight per cu. yd. 2748 lb. Forty per cent of the screenings are retained on the 10-mesh sieve, and 88 per cent on the 60-mesh. When washed, the sample yielded 4.7 per cent dirt. The effective size is 0.21 mm. and the uniformity coefficient 8.00.

This would be a good structural sand, if occurring in sufficient quantities, and at available locations. Most of the Lamotte, however, is too fine-grained to be of the highest value for building sand. The detailed mechanical analysis of this sand is given in an accompanying table (p. 126).

THE BONNETERRE.

This formation is essentially a dolomite, but contains occasional sandstone lenses near the base, which, however, are of no present or future importance as a source of sand.

THE DAVIS.

The Davis formation consists of shale and dolomite, and is practically without sandstone members.

THE DERBY.

This is a dolomite formation, practically without important sandstone beds.

THE DOERUN.

This formation also is practically without sandstone members.

THE POTOSI.

Like the Derby and Doerun, the Potosi contains practically no sandstone.

THE EMINENCE.

There are no sandstones of importance in this formation.

THE PROCTOR.

The Proctor formation is without important sandstone members.

THE GUNTER.

This sandstone, formerly known as the "Third Sandstone" and the Cole Camp sandstone and now usually considered as the basal member of the Gasconade, is the first prominent or persistent sandstone above the Lamotte. It varies from two to at least thirty-five feet in thickness, the variation being due to the unconformable surface on which it rests. The formation is usually rather thin-bedded and shows numerous ripple marks and much cross bedding. It is a quartz sandstone varying from coarse to fine in texture, and the grains are usually well-rounded and polished. Locally, they are more angular where there has been secondary quartz enlargement. As a rule, the formation is firmly cemented and is quarried for flagstone at certain places. At a few places only, is it loose and friable. In color it varies from white through various shades of yellow to deep red-brown. The sandstone over much of the area where it is known to outcrop is very much too thin to be quarried for any purpose, though at a few places it might be of sufficient thickness. Swallow[1] reports that on the lower Niangua it occurs in sufficient quantity and suitable purity for glass sand. The writer has not seen these outcrops, but it is probable it will not become a glass sand producer because of the abundance of the purer and more available St. Peter. It is too fine-grained to be suitable for concrete, but it might supply a local demand for plastering sand if coarser material were not available.

In Miller County[2] the formation outcrops in a few small patches along Osage River and its deeper tributaries, but does not reach a thickness greater than 18 feet.

In the southwest corner of Morgan County[3] there are prominent outcrops along Osage River and Proctor Creek, and smaller outcrops near Gladstone in the southeast corner. The thickness in Morgan at places reaches 35 feet.

In Benton County,[4] the same formation outcrops along the Osage, near the mouth of Cole Camp Creek, from which locality it derived the name Cole Camp sandstone.

---

[1]Geol. Survey of Missouir, First and second annual reports, p. 129, 1855.

[2]Ball, S. H., and Smith, A. F., Missouri Bureau of Geol. and Mines, vol. 1, 2d series, pp. 26-29, 1903.

[3]Marbut, C. F., Missouri Bureau of Geol. and Mines, vol. 7, 2d series, pp. 26-27 ,1907.

[4]Winslow, Arthur, Missouri Geol. Survey, vol. 6, p. 364, 1894.

In Camden[1] County the formation is exposed at numerous places along the course of Osage River, and is reported[2] as occurring along Niangua River in the vicinity of Hahatonka.

In the northern part of Dallas County[3] a small inlier of the Gunter is reported near Tunas along Niangua River.

In Ste. Genevieve County[4] the Gunter has a limited development, the thickness varying up to a maximum of about 30 feet. It thins rapidly to 7 or 8 feet and in places disappears entirely. In color it varies from white to brown and is of medium grain.

With the exception of the foregoing occurrences, details of the distribution of this formation are wanting, but it probably has no important development outside the counties mentioned. The formation is of little prospective value as a source of sand.

THE GASCONADE.

Aside from the Gunter, this formation carries only occasional thin sandstone lenses and these have no economic significance.

THE ROUBIDOUX.

This formation was known to the older writers as the "Second Sandstone" (in part), and in the Miller County report it is called the St. Elizabeth formation. The chief sandstone member of the formation in that county was known as the Bolin Creek. In Winslow's report (Vol. VI, 1894) the name Moreau sandstone is applied to what is now known as the Roubidoux, and he gives the term Roubidoux to the St. Peter.

The Roubidoux probably has a wider surface outcrop than any other sandstone in Missouri. It is undoubtedly of far less economic value than the St. Peter or the Everton, but it probably ranks next to those formations in the possibility of commercial exploitation. The formation is widely variable in its characteristics from point to point, and separate descriptions will be given for all those counties for which there are sufficient available data.

PHELPS COUNTY.

Probably the most detailed study made of the Roubidoux was that done by Lee[5] in the area of the Rolla Quadrangle.

---

[1]Winslow, Arthur, Missouri Geol. Survey, vol. 5, p. 367, 1894.

[2]Ball, S. H., and Smith, A. F., Missouri Bureau of Geol. and Mines, vol. 1, 2d series, p. 26, 1903.

[3]Hughes, V. H., Missouri Bureau of Geol. and Mines, 46th Biennial Report, p. 37, 1911.

[4]St. Clair, Stuart, Unpublished manuscript.

[5]Missouri Bureau of Geol. and Mines, vol. 12, 2d series, pp. 21-34, 1913.

DISTRIBUTION.

In the northeastern part of the county the Roubidoux outcrops sparingly in the deeper valleys. Over the southern and western portions of the area it is widely exposed, outcropping on the hill tops and upper slopes and forming the dominant surface rock over the county.

THICKNESS.

The formation varies from 100 to 150 feet thick, with an aggregate of from 30 to 60 feet of sandstone.

GENERAL DESCRIPTION.

Lee has divided the formation into seven members, of which four are sandstones. His table of members is appended:

		Feet
7	Sandstone, white ripple-marked with chert grains	1– 3
6	Dolomite, gray, finely crystalline, soft, interstratified with chert and sandstone sheets, silicious oolite, cotton rock, and sandstone lenses	30
5	Sandstone and oolitic sandstone, reddish-brown to pink, medium-grained	2–10
4	Dolomite, gray, medium to finely crystalline	30
3	Sandstone, reddish-brown, medium-grained, ripple-marked, cross-bedded and sun-cracked	20–30
2	Dolomite, gray, medium crystalline, somewhat cherty, interstratified with thin, sometimes thick, lentils of sand stone and beds of chert	35–45
1	Sandstone, sun-cracked and ripple-marked, interbedded with dolomite	3–20

Member No. 1 is a sandstone from 3 to 20 feet thick, with dolomite lenses. It consists of moderately angular quartz grains with a few chert pebbles, and is usually highly ferruginous. It is probably of no commercial value.

Member No. 3 is a sandstone varying from 20 to 30 feet in thickness, and is probably the equivalent of the Bolin Creek sandstone of Miller County. It is the most important member of the Roubidoux in the Rolla Quadrangle. For the most part it consists of clear quartz grains, frequently angular from secondary enlargement, and carries occasional chert fragments. The grains are reported as moderately fine and weakly cemented with iron oxide. For the most part, the rock is friable. In places it is white, though the prevailing color due to iron stain is reddish or brownish. Ripple marks, sun cracks, and cross

bedding are common. At few places, if at all, does the sand reach sufficient purity for glass manufacture, and in general, it is too fine-grained to be of value for structural purposes, except locally where coarse creek sands are not to be had.

Member No. 5 varies from 2 to 10 feet thick. For the most part it does not outcrop prominently and is of no probable value. Member No. 7 is a sandstone varying from one to seven feet in thickness and has no possible economic significance.

Other thin sandstone lenses occur in the dolomite members, but they are not worthy of separate discussion.

The eastern part of the County has not been studied in detail, but it is probable from isolated observations that the foregoing divisions do not apply exactly as given much beyond the eastern edge of the Rolla Quadrangle. It is certain, however, that there is one sandstone in this area much more prominent than the other members and this is probably the equivalent of Lee's third member (second sandstone member). It quite possibly also includes the fifth member, since it is probable that the fourth member is very thin or wholly absent in the vicinity of St. James.

In a few places the sandstone is fairly white, but it probably could not compete with the St. Peter for glass sand.

Screen tests were made on several Roubidoux samples and the results are given in an accompanying table (p. 126).

Sample 199 is from Meramec Springs and is probably from the basal sandstone of the formation. It is highly ferruginous and moderately indurated. The sand is fairly sharp and consists of quartz grains with a very small proportion of chert fragments. It practically all passes the 20-mesh and 83 per cent is retained on the 60-mesh sieve. The specific gravity is 2.64, the voids 49.3 per cent, the effective size 0.2 mm., and the uniformity coefficient 1.55. It weighs 83.6 lb. per cubic foot, or 2259 lb. per yard. The dirt content is 4.8 per cent, most of which consists of a fine red clay. The sand washes nearly white. (See table, p. 126.)

Sample 212 comes from the second sandstone member about three miles southwest of Rolla. It is ferruginous and moderately well indurated, consisting of quartz grains with a considerable mixture of chert. It practically all passes the 20-mesh and 95 per cent is retained on the 60-mesh. It is unusually coarse for Roubidoux sand. The effective size is 0.28 mm., and the uniformity coefficient 1.39. It has 48.4 per cent

voids, weighs 84.4 lb. per cu. ft., and 2280 lb. per yard. The specific gravity is 2.62. It washes white and shows 5.3 per cent dirt, chiefly a fine red clay. (See table, p. 126.)

MILLER COUNTY.[1]

In the Miller County report the name St. Elizabeth was given to what is here called the Roubidoux, and the main sandstone, the Third Member (second sandstone member) of Lee was called the Bolin Creek.

DISTRIBUTION.

The formation outcrops extensively in a strip from one to six miles wide on the intermediate slopes on either side of Osage River through the central part of the county, and on the intermediate slopes of Big Tavern Creek in the southeast, and on Auglaize Creek in the southwest. Only along Big Tavern Creek in the southeast is the Bolin Creek member of sufficient thickness to have been mapped as a separate formation.

THICKNESS.

The formation varies from 70 to 160 feet in thickness, of which a variable proportion is sandstone. Outside the area of the Bolin Creek beds, the sandstone lenses rarely reach over 5 feet in thickness.

BOLIN CREEK MEMBER.

This member thins out northward and westward, and only reaches a sufficient thickness to map in the southeast corner of the County and on the upper waters of Big Tavern Creek and its tributaries. There it ranges from one to fifty feet, the variation being rapid and irregular. The formation is strongly cross-bedded, ripple-marked and sun-cracked. It is a well-rounded quartz sand, fairly well cemented, and varies in color from pure white to almost black, the greatest discoloration being on the surface. Considerable variation in size of grain obtains, the sand in places becoming rather coarse.

Except in a few places it is too stained to be of value for glass sand, and is probably too fine for structural purposes, except that when a better grade of sand is hard to secure it may be used for plastering.

[1]Ball, S. H., and Smith, A. F., Missouri Bureau of Geol. and Mines, vol. 1, 2d series, pp. 50-68, 1903.

MORGAN COUNTY.[1]

The Roubidoux formation outcrops over the intermediate slopes along the Osage and its tributaries in the south half of the County. It carries two sandstone lenses which thin and thicken irregularly, the thickest of which reaches a maximum variously reported from 18 to 40 feet. The report makes no mention of the character of the sandstone itself, but it is probable that it has little possibility of economic development.

MARIES COUNTY.[2]

The Roubidoux is reported as occurring in Maries County. In a general way, the distribution may be outlined as follows: In the northeastern and northwestern corners it occurs only in the deeper valleys. In the north central part it occupies the intermediate hill slopes on either side of the Gasconade, occurring well up toward the hilltops. It rises toward the south, and in the southern part of the County has a wide distribution as the highest rock. It is reported as a medium-grained, brown sandstone, in a few places varying to white. It ranges from friable to quartzitic, and from thick to thin bedded. It is strongly ripple-marked and carries thin beds of chert and dolomite. In thickness it varies from a few feet up to 55 feet. As in other counties, it probably has little possibility of becoming a producer of commercial sand.

OSAGE COUNTY.[3]

In this County the Roubidoux (called the Moreau Sandstone) is reported along Osage River, from near the mouth of Maries Creek southward to the county line. On Maries Creek about a mile above the mouth it dips northward below younger rocks; rises to the south, but again drops to near water level at the south line of the County. Its presence is noted on the Gasconade, but not described in detail. It is reported to be about 10 feet thick and of a buff color. It probably has no value.

[1]Marbut, C. F., Missouri Bureau of Geol. and Mines, vol. 7, 2d series, pp. 33-39, 1907.
[2]Broadhead, G. C., Reports on the Geological Survey of the State of Missouri, pp. 12-15, 1873.
[3]Broadhead, G. C., op. cit., pp. 31-32.

COLE COUNTY.[1]

Along Osage River the Roubidoux is shown on the map occurring from near the mouth of Maries Creek to the south line of the County. Along Moreau Creek it is shown occurring from the mouth of the Creek for a distance of between 10 and 20 miles upstream. The sandstone varies from 10 to 30 feet in thickness. The character of the formation is not described but it probably is of no value as a source of sand.

STE. GENEVIEVE COUNTY.[2]

The Roubidoux outcrops over only a small area in this County. It is best exposed in the vicinity of Washington and for a short distance north. It carries thin sandstone members near the top and at the base. The sandstones vary from 2 ft. to 30 ft. in thickness but average less than 10 feet. The grains are sub-angular and of medium size. Cross-bedding and ripple marks are common. The color is usually brown, or reddish-brown, but shows gray to white in places. These sandstones probably have no economic value.

OZARK AND DOUGLAS COUNTIES.

Shumard's[3] report on these counties was written when both were known as Ozark county. According to this report, the "Second Sandstone," now known as the Roubidoux, is best developed in the northern half of the County, in what is now known as Douglas. Here the formation consists of alternating dolomites and sandstones, one of the sandstones reaching 44 feet and another 77 feet in thickness, with several thinner sandstone members. Not enough detailed work has been done to make it certain that all this belongs to our present Roubidoux, but in the absence of careful studies, it will be left as Shumard classified it. It is exposed in heavy beds, along the head waters of all the creeks running south from the divide near the north line of Douglas County. It varies from coarse to fine, and from brown to pure white.

Information is not available to warrant any specific statement of the value of the formation in this County, but judging by information received from Wright County, it is probable

[1]Winslow, Arthur, Missouri Geol. Survey, vol. 6, p. 359 (map), 1874.
[2]St. Clair, Stuart, Unpublished manuscript.
[3]Reports on the Geological Survey of the State of Missouri, pp. 189-203, 1873.

that the Roubidoux in this region offers better prospects for glass sand, engine sand, and core sand than it does in most other parts of the State.

WRIGHT COUNTY.

Shumard[1] reports the presence of the "Second Sandstone" in this County on the south side of the divide now followed by the St. Louis and San Francisco Railroad across the southern portion of the county. It is also exposed north of this divide along Whetstone, Clark's, Lick Fork, Elk, and Beaver Creeks and Gasconade River, where it is said to form the lowest rock exposed, and to be confined to the valleys.

The following note, furnished by Mr. W. C. Hogoboom of the Missouri Bureau of Geology and Mines, describes briefly a deposit visited by him near Mansfield in the southern part of Wright County.

"About one mile south of Mansfield just west of the track of the Kansas City, Ozark and Southern Railroad is a hill of sandstone. The railroad has run a spur over to one side of the hill and has put up a small crushing plant. They have quarried some of the sandstone and crushed it to use for their rails, but expect in the future to sell to glass factories.

"Much of the sand is pure white but some of it contains red or brown streaks. It is often stained brown on the surface, but when broken is white underneath.

"The surface of the sandstone seems hard, but when once broken it crumbles and seems to contain very little cementing material.

"Where the stone has been quarried, a bluff about forty-five feet high is exposed for 200 feet or more, and more of the sandstone is seen outcropping where no quarrying has been done. It therefore seems probable that this whole hill is composed of sandstone. The development of the deposit is in charge of Mr. John C. Byng, Manager, K. C. O., and S. R. R., Ava, Mo."

LACLEDE COUNTY.

Shumard[2] reports the presence of the "Second Sandstone," probably the Roubidoux, along the Niangua, Osage Fork, and Gasconade Rivers, and along Mill, Bear and Cymblin Creeks. It varies from 10 to 70 feet in thickness, and is thin to massive-bedded. No details of its character are given and it is not possible to report on its prospective value.

PULASKI COUNTY.

Shumard[3] says that the "Second Sandstone" outcrops in every township of the County, forming the surface rock over

[1]Shumard, op. cit., pp. 205-212.
[2]Shumard, op. cit., pp. 213-222.
[3]Shumard, op. cit., pp. 223-232.

large areas capping the hills between the Gasconade, Piney, and Roubidoux Rivers, from the latter of which the formation takes its present name. It ranges from 20 to 100 feet in thickness, is quite variable in character, and contains numerous chert and dolomite members. According to the descriptions, it presents little probability of yielding commercial sand.

CRAWFORD COUNTY.

Shumard[1] describes the "Second Sandstone" as well developed in this County, reaching a maximum of 150 feet in thickness, mostly of rather massive sandstone. Over much of the County it forms the capping of the hills. Where observed by the writer near Cuba, Fanning, and Knob View, it shows few places where the purity is sufficient for a good grade of glass sand.

JEFFERSON COUNTY.

The "Second Sandstone" is reported by Shumard[2] to be sparingly developed in the County and to be highly ferruginous. It probably has no value.

CAPE GIRARDEAU AND PERRY COUNTIES.

According to Shumard[3] the "Second Sandstone" has considerable development west of the White Water River in Cape Girardeau County, but disappears northward and is not recognized in Perry. No details of its character are available, but it is safe to say it has no value.

Detailed county descriptions for the rest of the Ozark region are not available, but the Roubidoux is known to have a much wider distribution than is indicated in the foregoing discussion, and it is possible that in a few places it may prove to have value as a glass sand.

JEFFERSON CITY.

This formation is essentially a dolomite, but carries numerous thin sandstone lenses which rarely reach over five or ten feet in thickness and which are noted wherever the formation is exposed. The sandstones are usually badly discolored and strongly indurated. They are fine-grained, as a rule, and are of no possible

[1]Shumard, op. cit., pp. 243-257.
[2]Shumard, op. cit., pp. 304-313.
[3]Shumard, op. cit., pp. 258-289.

economic importance. Screen tests of Jefferson City sandstones are shown on p. 126. These tests were made for the sake of comparison with the Roubidoux and St. Peter, and not with any thought of possible value of the sand.

COTTER.[1]

This formation, which has heretofore been classed as part of the Jefferson City, is now separated in Ste. Genevieve County, where it carries occasional sandstone lenses up to about 10 feet in thickness. The same remarks apply as in the case of the Jefferson City.

POWELL.[2]

Like the Cotter, this formation has recently been separated from the older Jefferson City. In this State it is as yet mapped only in Ste. Genevieve County. Here it carries occasional thin lenses of sandstone, reaching a maximum thickness of about 10 feet but averaging considerably thinner. The sandstone is usually white and friable but too thin to offer any possible hope of development.

EVERTON.

Previous to 1914, the Everton was mapped as part of the St. Peter. It consists of two members, a lower sandstone and an upper limestone, dolomitic at a few points.

AREAL EXTENT.

The point farthest north in Missouri at which the Everton has yet been recognized is in the vicinity of Cedar Hill, on Big River. At this point (N. E. Cor. Sec. 34, T. 42 N., R. 4 E.), the following section was measured by Mr. J. S. Brown of this Bureau:

St. Peter—Massive white sandstone		35 feet
Everton	Sandy dolomite	5 "
	Thin bedded sandstone	15 "
	Cherty dolomite	5 "
	Sandstone, conglomeratic at base	5 "
	unconformity.	
Jefferson City—Buff dolomite.		

[1]St. Clair, Stuart, Unpublished manuscript.
[2]St. Clair, Stuart, Unpublished manuscript.

Beyond this point northward, the dolomite layers disappear, the Everton and St. Peter sandstones coming together to form a single sandstone from 75 to 100 feet thick. Southeasterly it extends across Jefferson County in a narrow belt varying in width from a few hundred feet to a mile or more. It lies just west of the St. Peter outcrop and crosses Isle du Bois Creek into Ste. Genevieve County about two miles above the mouth of that stream. From here it continues in the same general direction, passing just to the west of Bloomsdale, where it widens considerably, and then passes about three-fourths of a mile west of Zell and crosses the River Aux Vases, just north of the village of that name. At this point it is offset abruptly several miles eastward by a zone of intricate faulting, south of which it occurs in the County only in small detached areas.

As a distinct formation it has been traced south as far as Brewerville in Perry County. South of that point, the St. Peter was mapped without a topographic base and some time before the Everton was recognized as a distinct formation in this State. It seems probable that from Perryville to Dutchtown, west of Cape Girardeau, the Everton limestone splits up into various lenses, which render its recognition as a distinct formation difficult. Without the limestone to separate them, the differentiation of the St. Peter and Everton sandstones is nearly impossible. There are places where the St. Peter rests upon a highly sandy dolomitic limestone lithologically similar to the Everton. At first, this was supposed to be the Jefferson City, but it is now recognized that it may be Everton. If so, the Everton sandstone member has not been detected below it. Two localities showing this sandy dolomite are at the water tank south of Biehle, where the Cape Girardeau and Northern Railroad crosses Apple Creek (Sec. 5, T. 33 N., R. 11 E.), and at Dutchtown (Sec. 24, T. 30 N., R. 12 E.). Samples of the dolomites underneath the St. Peter at these two places were submitted to Mr. St. Clair of this Bureau, who has maped the formation in detail in Ste. Genevieve County and who probably is more familiar with the Missouri Everton than is any other Geologist. In his opinion, these samples resemble Everton more closely than they do Jefferson City. If they are Everton, there is, then, a definite unconformity between Everton and St. Peter, as boulders of this same sandy dolomitic limestone are found enclosed in basal St. Peter conglomerate. If this is Everton, the basal sandstone has thinned out to insignificant

proportions. In justice to Mr. St. Clair, it must be said that he has not studied these formations in the field in either Perry or Cape Girardeau Counties, and his suggestions are based wholly on hand specimens collected before the problem came up for consideration.

STRATIGRAPHIC RELATIONS.

The Everton rests on the Jefferson City, which formerly included the Powell, Cotter and Jefferson City proper, with clear unconformity, as is evidenced both by a thin basal conglomerate and by sudden variations in thickness of the basal Everton sandstone. It is apparently conformable below the St. Peter into which it seems to grade at most points. According to St. Clair there may be obscure unconformity between the two. (See p. 102.)

THICKNESS.

Owing to its unconformable base, the thickness of the Everton varies. This variation, though small, is abrupt. The sandstone member ranges from 18 to 65 feet in thickness, averaging about 45 feet, while the upper or limestone member averages not far from 25 feet. These figures apply to Jefferson and Ste. Genevieve Counties. No figures are available concerning the thickness from Brewerville southward in Perry and Cape Girardeau counties.

STRUCTURE OF THE BELT.

The Everton, where present, follows the curve of the St. Peter along the east flank of the Ozarks. (See St. Peter.) The dip varies, but averages from ½° to 5° in a general easterly and northeasterly direction. Just south of River Aux Vases, occurs a zone of distributive faulting with a trend approximately N. 70° W. The aggregate throw is large, the north side, in general, having dropped with respect to the south. Erosion on the south has shifted the outcrops of all the formations eastward down the dip for a distance of about five or six miles.

Minor structures of the belt include bedding, cross bedding and ripple marks. Bedding is more plainly marked, as a rule, than it is in the St. Peter. This is particularly true of the basal layers of the sandstone which are frequently thin and persistently bedded (see pl. XII, B), probably owing, in part, but not entirely, to the fact that longer exposure to the weather has

emphasized bedding planes. The upper part of the sandstone, particularly where it is capped and protected by the limestone, shows in places the same massive structure so characteristic of the St. Peter. Cross bedding in the sandstone, though frequently noted, was nowhere steep, intricate, or on a large scale. The limestone member is strongly cross-bedded in certain places. Ripple marks are fairly abundant in the lower thin-bedded portions of the sandstone, but are rare in the more massive phases. These ripples average much smaller than those usually seen in sandstone, many of them not being over ¼-inch from crest to crest.

PHYSIOGRAPHY OF THE EVERTON BELT.

From Crystal City in Jefferson County, southeast as far as Bloomsdale in Ste. Genevieve, the Everton frequently forms part of the prominent St. Peter-Joachim escarpment; at points, however, where the outcrop crosses the divides between the transverse streams, the belt widens and occupies considerable areas of rolling country. From Bloomsdale south to River Aux Vases, the escarpment becomes much less prominent, and the formation outcrops over a more gently rolling country. The general structure and physiography of the belt will be discussed in more detail in the section devoted to the St. Peter.

LITHOLOGIC CHARACTER OF THE EVERTON.

In chemical composition, the Everton is practically the same as the St. Peter. On page 122 is given a table of analyses of the St. Peter and Everton sandstones.

As in the St. Peter, the basal portion of the Everton sandstone, especially where it outcrops in low, flat exposures with only a soil cover, is frequently ferruginous and colored brown or deep red. On the other hand, the upper portion, where recently exposed or still covered and protected from infiltration of ferruginous solutions, is a remarkably pure white, weathering to a light-gray. Cliff exposures are especially pure. As in the St. Peter, the iron was probably introduced during the erosion of the formation. Greenish clay seams or "mud seams" were noted and are probably of the same nature as those observed in the St. Peter (pp. 125-126, and 128).

The sandstone consists of practically pure quartz grains, well-rounded and polished and with a characteristic frosted

appearance. The size and degree of uniformity closely approach that of the St. Peter.

The degree of cementation varies considerably, the whiter phases, as a rule, being the most friable. Usually they can be easily crushed by the fingers into their constituent grains. Even the whiter phases are at places more firmly cemented. The ferruginous sandstone is cemented by iron infiltrated from foreign sources, and is usually much harder than the whiter portions of the formation.

FAVORABLE LOCALITIES.

Localities favorable for the production of glass sand from the Everton will be mentioned under the St. Peter section in the detailed county descriptions of Jefferson and Ste. Genevieve counties.

USES.

The Everton, like the St. Peter, is suited for glass manufacture, moulding sand for steel casting, core sand, refractory sand for fire brick and for furnace linings, and for the manufacture of sand-lime brick. Like the St. Peter, also it is too fine-grained and too high in voids for structural purposes. Its suitability for various uses is discussed more in detail in the section devoted to the St. Peter.

THE ST. PETER SANDSTONE.

Up to the date of the present writing, the St. Peter[1] (Saccharoidal, or "First Sandstone" of the older geologists, and known locally as the Pacific sandstone, the Crystal City sandstone, and the Cap au Gres sandstone) is the only productive glass sand formation in the State. The St. Peter series as described in the following pages includes the St. Peter sandstone proper and in many places the Everton formation. The latter has been described in detail in a preceding section, as consisting of a limestone and a sandstone in descending order below the regular St. Peter sandstone.

[1]Winslow in Geological Survey of Missouri, vol. VI, 1894, calls this the Roubidoux.

AREAL EXTENT OF THE ST. PETER.

Aside from a few small outliers which will be noted later, the main area covered by the formation is limited to eastern Missouri, forming through a broad curve the northeast margin of the typical Ozark region between Cape Girardeau on the southeast and Mineola, Montgomery County, on the northwest. It forms an extremely irregular belt varying from one to ten miles in width. The width of the general area over which outcrops of the sandstone are to be found at the north is in places as great as ten miles or more. Owing to the depth and completeness of dissection just north of Missouri River and to the steep hillsides along which the formation occurs, the actual width of the outcrop is usually less than a quarter of a mile and often not more than 200 yards. This is, of course, due to the steep slopes. On the other hand, because the region in Perry and Cape Girardeau counties is little dissected, the width of the total area over which exposures are to be found is less than in the north, averaging from one to five miles; but because of the gentle slopes the outlines of the belt here are much more regular, and most of this strip from one to five miles in width is actually immediately underlain by the formation. The total length of this belt is nearly 150 miles in a straight line. Taking into account the irregularities due to the marked dendritic dissection of the northern half of the area, the actual length of the continuous contact is perhaps five times as great.

At the extreme south, the belt terminates abruptly in the Mississippi River bluffs at Dutchtown about eight miles west of Cape Girardeau, where it is cut off by the Mississippi lowland. From this point it extends in a broad belt about N. 20° W. across Cape Girardeau County, and lies just to the west of Jackson and Oak Ridge. It then passes out of the County at the northwest corner, and runs through the extreme northeast portion of Bollinger County into Perry County. Across Perry it continues in the same general direction, passing just west of Perryville, and becoming considerably narrower in the northern part of the County. Near the north boundary of Perry County there is a zone of complicated faulting (see section on structures) which crosses the strike of the formation, the north side being offset rather abruptly westward to the vicinity of River aux Vases in Ste. Genevieve County, a distance of approximately five miles. Along the south side of the fault, an arm of the

formation extends south eastward across secs. 8, 9, 10, 11, 14, 15 and 16, T. 36, N., R. 10 E., to the vicinity of Lithium.

From River aux Vases, the formation extends N. 30° W. through Bloomsdale, crosses Isle du Bois Creek into Jefferson County at a distance of about two miles from the Mississippi, and parallels that river at about two miles distant northwest to Crystal City. From here it turns more to the west, passes about N. 55° W. across Jefferson County, just barely enters the southwest corner of St. Louis County, crosses the northeast corner of Franklin County at Pacific, and reaches Missouri River at Klondike in the southwest corner of St. Charles County. From here the direction changes to approximately N. 70° W., and the belt roughly parallels the course of Missouri River across the southern portion of Warren and Montgomery Counties. Along the western boundary of Montgomery County and in the eastern part of Callaway County, about 10 to 20 miles north of Missouri River, the average thickness of the formation decreases by nearly one-half, later erosion has removed it over large areas, and in addition it passes unconformably underneath later beds, and west of central Callaway County is exposed only as occasional isolated inliers, where erosion has cut through the overlying beds.

In addition to the continuous belt described above, the following isolated patches of St. Peter have been noted. In Lincoln County, an east-west fault passing just north of Winfield exposes on the north (upthrown) side perhaps five square miles of the formation. This sandstone outcrops in a very irregular shaped body, about five miles in its greatest east-west extent, and about three miles north and south lying along the Mississippi River bluffs and westward. In the northwest part of the same County, folding and faulting expose small patches of the formation along creek beds in secs. 4, 5, 28 and 33, T. 51 N., R. 1 W.

In Perry County the great zone of faulting along the Mississippi River bluffs between McBride in sec. 17, T. 36 N., R. 11 E., and Wittenberg, in sec. 17, T. 34 N., R. 14 E., brings up patches of the St. Peter in secs. 30 and 31, T. 36 N., R. 12 E., and in sec. 25, T. 36 N., R. 11 E. Other small patches may occur along this faulted area.

The continuous belt of St. Peter practically ends at the west line of Montgomery County. Isolated inliers and outliers of what are in all probability the St. Peter are known across Callaway and Boone. Many scattered patches of sandstone west and south of these counties have been referred to the St. Peter,

but they may include almost anything from the Roubidoux to the Pennsylvanian sandstones. Few, if any, of them have any present or prospective commercial importance.

STRATIGRAPHIC RELATIONS OF THE ST. PETER.

RELATION TO THE JOACHIM.

The St. Peter throughout the above-described belt is overlain with apparent conformity by the Joachim ("First Magnesian Limestone" of the older writers) which everywhere presents about the same general character of a moderately thin-bedded buff to grayish-yellow dolomite or dolomitic limestone, which in many places is sandy at the base and is interbedded with thin laminae of greenish shale. This greenish sandy shale is particularly characteristic of the immediate contact between the St. Peter and the Joachim, and is well shown in the quarries at Pacific.

In certain places toward the southern end of the belt in Perry and Cape Girardeau counties the base of the Joachim carries several thin sandstone beds, varying from a few inches to at least six feet in thickness. In areas of few outcrops and of no topographic maps, the thicker sandstone beds within the Joachim have caused trouble in mapping. This is especially true in central Cape Girardeau County where, on account of the occasional prominence of outcrops of thin sandstone beds which were easily mistaken for the St. Peter, it was frequently difficult to draw a definite boundary between the St. Peter and the overlying dolomite.

Quite arbitrarily the boundary between the two formations has, as far as possible, been drawn at the top of the main mass of the St. Peter, throwing all the thin sandstone beds into the Joachim. It may possibly be found necessary later to change this division. The position decided upon for the boundary was chosen largely on economic grounds, in view of the fact that the thinner sandstone beds could not possibly have any present or prospective value for glass sand. These transition beds of sandstone may be seen to advantage in the NE. ¼ sec. 36, T. 33 N., R. 11 E., in the SW. ¼ sec. 17, T. 32 N., R. 12 E., and at several points near the center of sec. 19, T. 32 N., R. 12 E., all in Cape Girardeau County. In all three of these localities the sandstone lenses are well exposed along the public roads.

Near the northwestern end of the belt, in Warren and

A. Contact of St. Peter sandstone below Joachim dolomite, in an abandoned quarry near Pacific, in St. Louis County. Note how cross bedding gives a deceptive appearance of discordance.

B. The St. Peter-Joachim escarpment between Crystal City and Silica, Jefferson County.

Montgomery counties, the Joachim at several points becomes decidedly brown, and rather more coarsely crystalline, and it is frequently difficult upon hasty examination to distinguish it from the so-called Devonian brown limestone reported from this region, some of which may even prove to be Joachim.

The Joachim everywhere rests with apparent conformity on the St. Peter, usually with complete gradation from the one to the other through a thickness varying from a few inches in the northern and central parts of the belt to several feet in the southern counties.

In a few places, especially in the quarries where the contact can be minutely studied, there is the appearance of slight discordance between the St. Peter and the Joachim (Pl. XIII, A), the latter resting on successively lower strata of the sandstone. This can be seen in the Tavern Rock and Pacific Glass Sand quarries at Pacific. It is believed that the apparent stratification of the sandstone is really cross bedding which, while not remarkably developed, is not unknown in the St. Peter throughout its entire extent in the State. That the apparent discordance means any considerable break in sedimentation seems extremely unlikely, in view of the usual gradation of the one formation into the other. Although it has been interpreted as an unconformity, it seems almost certain that this phenomenon means no more of a break than do many cases of cross bedding seen with the St. Peter itself, which produce the appearance of quite as great discordance. Ulrich[1] considers the two conformable.

RELATIONS TO THE JEFFERSON CITY.[2]

Wherever the base of the St. Peter series (including the Everton) is seen to rest on the Jefferson City formation ("Second Magnesian Limestone" of the older geologists), the relation is that of erosional unconformity. This formation is extremely variable, ranging from thin-bedded, gray and buff argillaceous dolomite, known locally as cotton-rock, to a massive, pitted gray dolomite. Chert is abundant at all horizons, and especially so, as a rule, near the contact with the St. Peter. The formation contains many lenses of sandstone varying from a few inches up to five or more feet in thickness but rarely continuous over great distances. In many localities these lenses yield abundant

[1] U. S. Geol. Survey, Prof. Paper No. 24, p. 96, 1904.

[2] Jefferson City is here used in the old sense to include the Powell and Cotter, which were not differentiated when the field work for this report was done.

residual sandstone blocks, which, where outcrops are few, are likely to be mistaken for the residuum from the St. Peter, and which cause confusion in mapping contacts. Such beds of sandstone within the Jefferson City have been noted in Montgomery, Warren, and Jefferson Counties. In the latter County, a prominent ridge running through the center of sec. 26, T. 40 N., R. 5 E., is capped with sandstone, which can only occasionally be seen in place but which yields very abundant residual sandstone blocks. While it may be an outlier of the St. Peter or the Everton, it is, owing to its apparent conformity (?) to the Jefferson City dolomite, believed to be a member of the latter, especially so since the dip of the St. Peter, if it is anywhere nearly constant, should carry the latter considerably above the top of the ridge in question.

At all points where the contact between the two is clearly exposed, the St. Peter series rests with evident unconformity on the Jefferson City. Perhaps the most frequently noted evidence of this unconformity is the sudden change in thickness in short distances of the St. Peter or of the Everton sandstone. Crane reports eleven observations in Warren and Montgomery counties alone of sudden changes of from 10 to 25 feet in the altitude of this basal contact, while the upper or Joachim-St. Peter contact is not affected. This shows that the sudden change is really the result of unconformity and not of faulting. Similar relations were noted in many other places. South of Crystal City in Jefferson County where the Everton is known to be present, the basal Everton sandstone varies within short distances between 20 and 40 feet.

In several places in Jefferson, Perry and Cape Girardeau counties, basal conglomerates of limestone and flint pebbles and bowlders occur in the lower part of the St. Peter series. A very coarse conglomerate of this type is well exposed in a cut along the Cape Girardeau and Northern Railroad at the water tank in the N. E. ¼ N. E. ¼ sec. 5, T. 33 N., R. 11 E., in Cape Girardeau County about midway between Biehle and Hilderbrand. Other conglomerates not so coarse as this were noted at several other places. The pebbles in these conglomerates are characteristically angular and resemble the flints and dolomite fragments in the residual soil of the Jefferson City formations at the present time. This basal conglomerate, due to overlap, is of varying age. At the north it may be the St. Peter; in Jefferson and Ste. Genevieve counties, and in the northern part

of Perry County it is definitely Everton in age, while farther south it may be in part Everton, in part St. Peter.

Another evidence of the unconformable relations of the two is to be noted in the much weathered condition of the Jefferson City at many places underneath the St. Peter series. In many places they are separated by a peculiar phase that is hard to classify as part of either formation. It consists of a nearly structureless mass of very heterogeneous composition with apparently complete gradation from massive chert to almost pure sand, the whole marked by numerous pockets of clay some of which show slight stratification. This peculiar contact phase, which is present at a good many places in the southern counties of the belt, appears very much like uneroded and highly oxidized remnants of an old residual Jefferson City soil. This appearance is much strengthened by the angularity of the pebbles in this basal layer, which can almost be duplicated in the recent residuum of the Jefferson City.

Much of this residual chert is included in the lower few feet of the sandstone. There has apparently been some solution and rearrangement of the silica, so that at many points it looks more like true chert layers in the sandstone than like a basal conglomerate; but there are other points where the conglomeratic nature of the material cannot be doubted. Crane notes that the base of the sandstone is notably cherty in Warren and Montgomery counties also, and sometimes goes so far as to use this peculiar phase to mark the base of the St. Peter where contacts could not be found. Mehl in his work for this Bureau noted the same features in Ste. Genevieve County.

RELATIONS OF THE ST. PETER PROPER TO THE EVERTON.

From the vicinity of Crystal City south into Perry County, the St. Peter sandstone rests with apparent conformity, but possibly with slight erosional unconformity, on the Everton formation into which at places it seems to grade. This latter consists of an upper member of sandy cross-bedded limestone and a lower member of sandstone in most respects similar to that of the St. Peter. The Everton in turn rests with very apparent unconformity on the Jefferson City exactly as does the St. Peter, where the latter two are directly in contact. It is entirely probable that in Perry and Cape Girardeau counties thin areas of the Everton may have escaped detection. The unconformity is one with overlap, the area of deposition being

greater during St. Peter than during Everton time. It is also probable that a slight recession of the sea took place at the close of Everton deposition.

THICKNESS.

From the northern part of Perry County to the extreme northwest end of the belt, over which area the sandstone is well dissected, frequent and reliable measurements of the thickness have been made. From Perryville south, no thoroughly reliable estimates of the thickness have been possible. Throughout the belt the St. Peter sandstone proper averages not far from 80 feet in thickness. Owing to the unconformity at its base, there are sudden variations within short distances, but these are usually of small magnitude.

The minimum original thickness noted by Crane was ten feet, and occurred in Montgomery County in the N. ½ sec. 28, T. 48 N., R. 6 W. In this vicinity the formation thins considerably, averaging about 50 feet. The maximum reliable observation made also by Crane, shows 135 feet of St. Peter, the base resting in an old erosion valley in the Jefferson City and thinning rapidly to about 85 feet in only a short distance. This is in the NW. ¼ sec. 22, T. 46 N., R. 4 W., in Warren County. At Klondike in St. Charles County and at Pacific in Franklin County, measurements show that the sandstone is about 100 feet thick. In the vicinity of Crystal City and Silica in Jefferson County, it averages about 60 feet and maintains this thickness south to the Ste. Genevieve County line.

In Ste. Genevieve County in the N. ½ NE. ¼ sec. 29 T. 39 N., R. 7 E., the writer measured 100 feet, and St. Clair reports about 90 feet from a few miles farther north. An estimate based in part upon a well record just southwest of Brewer in Perry County, places the thickness between 125 and 150 feet, but this may include the Everton. At Perryville, about a mile east of the outcrop of the belt, a well record shows the sandstone to have a thickness of 82 feet, overlain by 16 feet of alternating sandstone and limestone layers which constitute the transition described on a former page. All of the above figures represent the complete original thickness where overlain conformably by the Joachim.

A careful measurement in the SW. ¼ sec. 8, T. 41 N., R. 5 E., about 15 miles northwest of Crystal City, shows 50 feet of thin-bedded sandstone and dolomite overlain by 20 feet

of dolomite, probably Everton, followed by 35 feet of St. Peter. The contacts were all well exposed. Other measurements in the vicinity range from 35 to 50 feet.

In Cape Girardeau County there were few good opportunities for measuring the thickness of the formation. It is only very slightly dissected, the belt is wide, and at no points do the upper and lower contacts approach each other much more closely than a mile apart. Since the formation is not strictly horizontal but dips from ½ to 5 degrees in a general easterly direction, it is impossible to make a simple direct aneroid or hand-level measurement of the thickness. The dip must be taken into account, and a calculation made for each measurement. At Millerville in the SW. ¼ sec. 23, T. 32 N., R. 11 E., a well went through nearly 85 feet of the sandstone. This is near the western edge of the belt, where a considerable but unknown amount of the upper part of the formation has been removed by erosion. Two wells at Jackson are reported with 126 and 147 feet of the St. Peter and are said to be bottomed in the sandstone. This may include the Everton. A well at Cape Girardeau goes through only 60 feet of St. Peter, passing completely through the formation.

Just east of Millersville the eastward dip of the Joachim is variable, the maximum being about three degrees at its contact with the St. Peter. In a straight east-west line at right angles to the strike, the upper and lower contacts are separated by a distance of 1½ miles. The upper contact is 70 feet (aneroid measurement) above the lower. Figure 2 illustrates the ordinary method of obtaining the thickness in such a case.

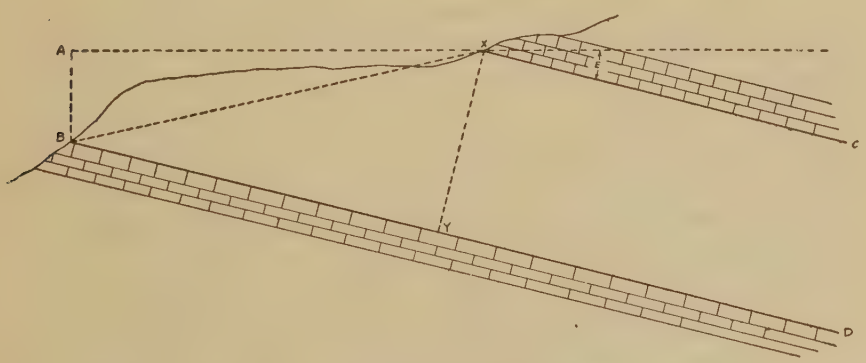


Fig. 2. Sketch showing method of computing thickness of formations.

AX is the horizontal distance between the upper and lower contact at right angles to the strike, scaled from the map, and in this case, is 1½ miles. AB is the vertical difference in altitude between the contacts. In this case the upper contact is 70 feet above the lower. Angle E is the angle of dip. In this case, the dip varies up to three degrees in the vicinity of X, the upper contact, and an average of 1½° was chosen. XY, perpendicular to XC and BD, is, of course, the desired quantity. Solving for XY either graphically or trigonometrically gives a thickness of about 275 feet. Of course the error in this method enters through incorrect measurement of the angle of dip. The beds are gently flexed on a minor scale all through the region. In the sandstone itself, bedding is very indistinct and bedding and cross bedding are usually not to be told apart. It is probably an unwarranted assumption to suppose that the dip observed at the upper contact remains perfectly constant over the whole width of the sandstone belt. Still further than this, slight irregularities of bedding make it almost impossible to read dips more closely than between 1 and 2 degrees. Bearing in mind that an error of 1 degree in dip makes an error of about 90 feet in the calculated thickness to each mile of measured width of outcrop (AX), it is clearly seen that with a formation which averages perhaps 80 to 100 feet thick, there is a strong probability of an error of over 100 per cent in calculated thickness.

The above computation gives a thickness of about 275 feet. A similar computation in sec. 6, T. 31 N., R. 12 E., about five miles straight west of Jackson, gives a thickness of about 200 feet. Though not very much weight can be given them, all these computations suggest a thickening of the sandstone at the southern end of the belt, and are in line with the evidence of the well at Millersville (p. 113) and with the wells at Jackson. It is probable that these estimates include Everton as well as St. Peter.

Shumard[1] in the older reports assigns to this sandstone a thickness of 100 feet in Cape Girardeau County and 200 feet along the Mississippi River bluffs, between the mouth of the Bois Brule and the mouth of the Cape Cinque Hommes in Perry County. This latter is a faulted inlier of the formation isolated in surface outcrop from the main belt. It is possible that the thickness assigned is excessive, as most of this area is complexly faulted.

[1]Reports of the Geological Survey of the State of Missouri, pp. 268 and 285, 1873.

[1]Potter assigns a thickness of 65 feet to the formation in Lincoln county along the Mississippi River bluffs, where it is brought up by the Cap au Gres fault. Along this same fault, a well on the farm of D. B. Trower in the NE. ¼ of sec. 10, T. 49 N., R. 2 E., was reported to have passed through 35 feet of soil and 82 feet of St. Peter and to be bottomed in sandstone. Since this formation outcrops on the brow of the hill not over 10 feet below where the well was drilled, the great depth of soil reported must rest in an old channel in the sandstone. The well therefore must cut not less than 100 feet and probably more of St. Peter. How much of this apparent thickness may be due to high dips in the sandstone occasioned by drag along the fault near which the well is located, it is impossible to say. According to Weller[2] the same sandstone has a thickness of 150 feet between West Point and Dogtown, near the Cap au Gres fault, in Calhoun County, Illinois. This is just across the Mississippi River from the Missouri outcrops previously cited.

STRUCTURE OF THE BELT.

FOLDING.

Southeast Missouri consists of a great quaquaversal dome known as the Ozark uplift, from which the rocks dip outward rather gently in all directions. Flanking the northeast margin of this dome, the St. Peter swings in a wide irregular crescentic belt from near Cape Girardeau on the southeast to the vicinity of Danville on the northwest. The position gives it dips of from one-half to five degrees in a general northeast direction, easterly dips being most marked at the southern end of the belt and northerly dips at the northwest extremity. These dips are far from constant, there being many minor flexures of the formation. Local dips to the west and south have even been observed in places.

Secondary folds of sufficient size to effect the trend of the formation were noted in a few places. In the N. ½ secs. 28 and 29, T. 36 N., R. 11 E., north of Brewer in Perry County, a rather sharp anticline, with axis N. 15° E. and dips of from 5° to 20° on the flanks, carries the formation in a rather well-marked curve to the northeast. At Crystal City in Jefferson County a sharp fold with a nearly east-west axis, with a very low dip on the

[1]Potter, B. W., The geology of Lincoln County; Geological Survey of Missouri; Iron Ores and Coal Fields, pt. 2, p. 224, 1872.

[2]Weller, Stuart, Illinois Geol. Survey Bulletin No. 4, p. 221, 1907.

south flank and steep dips on the north, carries the formation eastward along Plattin Creek to the Mississippi River bluffs. According to Crane, a sharp monocline with an axis about N. 45° W. and easterly dips of 10° to 15° is responsible for the inliers of St. Peter along Femme Osage Creek and its branches in the vicinity of Schluersburg in the southwest corner of St. Charles County. Crane also reports a pronounced anticline, with a general east-west trend and 10° to 20° dips on both flanks, passing through Mineola in Montgomery County. This fold is responsible for the inliers of the Jefferson City and St. Peter exposed along Loutre River. Inliers of the Jefferson City and St. Peter along Little Bear Creek about three miles north of McKittrick, along the Montgomery-Warren County line in sec. 12, T. 46 N., R. 5. W., may represent a southeast extension of the fold at Mineola, although the fold was not noted in the intervening region.

FAULTING.

Between River aux Vases (sec. 35, T. 37 N., R. 8 E.) in Ste. Genevieve County and McBride (sec. 17, T. 36 N., R. 11 E.) in Perry County, and trending about N. 70° W., is a zone of intense and complex faulting. Most of the individual faults trend in the general direction of the zone, splitting up or coalescing in the most intricate manner. Along this zone are several small blocks of St. Peter, caught in between the faults. The combined throw of the faults must be approximately 1000 feet, the north side having dropped with respect to the south. The faulting seems to be normal and is intermediate between the strike and the dip types, approaching most nearly to the latter. As a result, the most marked effect of the disturbance on the St. Peter formation is to offset the belt abruptly, shifting the outcrop on the upthrown and eroded side (the south) about five or six miles down the dip of the beds to the eastward. At McBride (sec. 17, T. 36 N., R. 11 E.) the zone of faulting turns rather sharply southward (about N. 45° W.) and parallels the Mississippi River bluffs as far as Wittenberg (sec. 17, T. 34 N., R. 14 E.), near the south line of Perry County. Along this portion of the fault are located the inliers of St. Peter already noted on p. 107.

The Cap au Gres fault in Lincoln County has already been mentioned. On the Illinois side, the fault is well exposed in the river bluffs just north of Dogtown where it is reported by Wel-

ler[1] to have a throw of about 720 feet. Passing to the Missouri side, the fault intersects the river bluffs near the center of the east line of sec. 11, T. 49 N., R. 2 E., about midway between Winfield and Foley. From here it extends in a very irregular line northwestward, passing out of the County at the extreme northwest corner. The south side dropped with respect to the north, the displacement varying greatly along the fault. Potter[2] estimated the maximum throw in Lincoln County to be not far from 400 feet, sufficient at least to bring the St. Peter on the north into contact with Mississippian beds on the south. Well records reported by M. E. Wilson,[3] of this Bureau, indicate that the throw must be considerably greater, probably between 600 and 800 feet. There is some evidence in secs. 3 and 10, T. 49 N., R. 2 E. that the fault is broken up into a zone of minor disturbances. In addition to the area of St. Peter brought up on the north side of this fault in the vicinity of Foley along the Mississippi River bluffs, several small patches already mentioned (p. 107) are exposed in the northwest corner of Lincoln County along creek beds north of the fault near Silex and Whitesides.

BEDDING IN THE ST. PETER.

At many points, this formation appears to be very massive and shows little or no trace of bedding. In places this massive effect is deceptive, and when viewed at a distance the larger features of bedding stand out distinctly. Along the face of fresh exposures, especially in the quarries, a faint color banding not uncommonly marks the bedding. In several quarries red ferruginous beds and greenish mud seams can be traced rather continuously. Long exposure oftentimes brings out by differential weathering a certain coarse massive appearance of stratification which is believed to represent bedding.

At the southern end of the belt in Perry and Cape Girardeau counties, many exposures show a somewhat thinner and more persistently bedded sandstone. It is possible that this, at least in part, may represent the Everton, the base of which is characteristically thin-bedded and the presence or absence of which has not been definitely proved south of Perryville.

---

[1]Illinois Geological Survey, Bull. No. 4, p. 221, 1907.

[2]The Geology of Lincoln County; in Geological Survey of Missouri; Iron ores and coal fields, pt. 2, p. 224, 1872.

[3]Personal communication.

CROSS BEDDING OF THE ST. PETER.

Cross bedding, while characteristic of the formation throughout much of its extent, is by no means always present. These false beds though often several feet in length are rarely steep and almost never intricate in arrangement. The cross-bedded structure is usually not particularly striking.

RIPPLE MARKS.

Although ripple marks were noted at a few places both at the north and near the southern end of the belt, they cannot be said to be characteristic of the formation. In fact, contrasted with the Roubidoux, Jefferson City, or Everton, they are comparatively scarce. Crane reports a 65-foot exposure of the St. Peter with ripple marks 20 feet from the top of the formation. The writer also saw ripple marks in a few places. However, there seems to be a tendency for the formation to be more ripple-marked near the base. Care must be taken not to confuse lenses of Jefferson City sandstone which frequently show many ripples, with the St. Peter, in which ripples are much rarer. Many ripple-marked residual slabs below the line of the lower contact of the St. Peter are probably from the Jefferson City sandstone lenses, and others are unquestionably from the Everton which is more frequently ripple-marked than is the St. Peter.

PHYSIOGRAPHY OF THE ST. PETER BELT.

The fact that the St. Peter is underlain and overlain by harder formations which resist erosion much better than the friable sandstone, coupled with the fact that it everywhere has a moderate northeasterly dip away from the Ozark center, accounts for its most marked topographic characteristic. This feature is the prominent escarpment which marks the site of the belt most of the way from Perryville in Perry County to its extreme northwest end in Montgomery County (Pl. XIII, B).

The escarpment, usually pronounced, faces southwest toward the Ozark center, and consists of very steep slopes or quite frequently of cliffs of St. Peter sandstone capped with the resistant Joachim which usually forms the sharp brow of the ridge. The inner lowland formed by the removal of the St. Peter is usually floored with the Jefferson City or with a thin patchy veneer of basal conglomeratic sandstone not yet

completely removed and belonging in part to the Everton and in part to the St. Peter.

Between Perryville and Missouri River, the area is drained by a large number of closely spaced short streams which flow directly into the Mississippi through steep, narrow ravines, frequently almost inaccessible. In one of these, Cliffdale Hollow, in the N. ½ sec. 27, and the S. ½ sec. 22, T. 40 N., R. 6 E., the gradient is so great near the head of the stream that it has cut not only through the Joachim cap but also completely through the St. Peter, exposing a small inlier of the Everton. This hollow is particularly interesting, because it contains a natural sandstone bridge of considerable size, the result of weathering and erosion along a joint plane.

From Perryville north to Missouri River the broad, open, rolling valleys of the inner lowland are in sharp contrast to the steep gorges that dissect the eastern slope described above.

In northern Perry County this inner lowland is drained by Saline Creek and its tributaries. Across Ste. Genevieve County the lowland is interrupted by the great zone of faulting. In the northern part of the County it is occupied by the tributaries of River aux Vases, Establishment Creek, and Isle du Bois Creek. In Jefferson County, Isle du Bois Creek, Saline Creek, Muddy Creek, Doolin Hollow, Selma Creek, Plattin Creek, Joachim Creek, and Big River, together with their tributaries, occupy the inner lowland. In St. Louis and Franklin counties, the Meramec and Missouri rivers occupy the same relative position. All of these streams break across the ridge in water gaps, some of which are very picturesque. Bloomsdale on Establishment Creek, Rush Tower on Muddy Creek, Selma on Selma Creek, Crystal City on Plattin Creek, Herculaneum on Joachim Creek, Byrnesville on Big River, Pacific on Meramec River, and Klondike on the Missouri, are all located at or very near water gaps through the escarpment.

North of Missouri River the ridge takes on a very different aspect, owing chiefly to the difference in the relative position of the dominant drainage in the two regions. South of the Missouri, the entire drainage is dominated by the Mississippi, which lies on the eastern slope. Hence there are a large number of short rapid streams on that slope and a smaller number of larger streams occupying the lowland and breaking across in occasional water gaps. At the north end of the belt the situation is just reversed. Here the escarpment practically parallels

and faces the Missouri which itself occupies the inner lowland. The dominant stream is on the scarp slope, and the secondary streams cross the ridge in the reverse direction. Thus, being nearer to its master river, the escarpment is much more deeply and irregularly dissected than farther south, giving it a much less regular and continuous effect. The fact that the rocks dip less steeply north of Missouri River also influences the dendritic dissection of the escarpment.

In addition to the facts noted above, there is another striking feature of the topography north of the Missouri worth noting. That river lies entrenched about 100 feet below the contact of the St. Peter and the Jefferson City. The latter formation being resistant, stands up in well-marked cliffs along the edge of the flood plain, leaving a distinct shelf of Jefferson City which stands as a much dissected plain about 100 feet above the River. This shelf, properly speaking, now constitutes the floor of the inner lowland, and to the north of it and overlooking it rise the steep slopes of the St. Peter scarp capped by Joachim. It is possible, of course, that this shelf represents a portion of an intermediate peneplain between the upper Ozark Plateau and the present flood plain. But as it occurs exactly at the contact between the resistant Jefferson City and the non-resistant St. Peter, it is much more likely that it represents a stripped structural plain uncovered by the natural recession of the St. Peter escarpment.

South of Perryville in southern Perry County and in Cape Girardeau County, the area covered by the belt of St. Peter is only very slightly dissected. As a result the sandstone has no marked topographic expression, the escarpment being almost entirely lost. The most notable feature is the nature of the soil, the sandy soil of the St. Peter belt being somewhat more subject to gullying than is the heavier residuum of the Joachim and Jefferson City formations. In this southern region, any possible topographic expression of the sandstone is further masked throughout much of its extent by a heavy mantle of loess.

Over most of its extent, especially where the escarpment is prominent, the base of the St. Peter is a favorable horizon for springs. The porous sandstone acts as an aquifer, and as the water seeps downward to the top of the less pervious Jefferson City dolomite or Everton limestone, as the case may be, it finds its easiest relief laterally and escapes as springs.

LITHOLOGIC CHARACTER OF THE ST. PETER SANDSTONE.

COMPOSITION.

The St. Peter is a remarkably pure quartz sand. Seventeen unwashed samples of the whitest sand, taken from fresh exposures and analyzed by the Survey's chemist, average 99.44 per cent silica and only 0.078 per cent iron oxide. The analyses are presented in the accompanying tabulation. Accompanying each analysis, is a statement of color, and it may safely be said that a very large percentage of white St. Peter samples will run over 99 per cent silica and less than 0.10 per cent iron oxide.

TABLE OF ANALYSES OF ST. PETER AND EVERTON SANDSTONES.

*Note—Samples 120 and 220 are Everton, the others are St. Peter.

No.	Ignition loss.	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	Total.	Color.	Locality.
4	0.25	99.07	0.11	0.46	0.01	0.07	99.97	Very slight buff tint	Near the "Big Spring," Sec. 25, T. 35N., R. 10E., Perryville, Perry Co.
11	0.16	99.34	0.043	0.297	0.10	0.04	99.98	Pure white, a few yellow spots	N. W. ¼, Sec. 5, T. 34N., R. 11E., Perry Co.
45	0.19	99.40	0.05	0.08	0.16	0.08	99.96	Pure white	N. W. ¼, Sec. 15, T. 44N., R. 2E., Franklin Co.
56	0.11	99.61	0.08	0.04	0.07	0.05	99.96	Pure white	S. W. ¼, Sec. 34, T. 43N., R. 3E., Jefferson Co.
57	0.29	99.32	0.07	0.12	0.15	0.09	100.04	Very slight gray tint	N. W. ¼, Sec. 18, T. 42N., R. 4E., Jefferson Co.
75	0.21	99.26	0.11	0.07	0.15	0.07	99.87	White with very pale buff tint	Sec. 28, T. 51N., R. 1W., Silex, Lincoln Co..
77	0.10	99.70	0.057	0.013	0.06	0.07	100.00	Pure white	Sec. 7, T. 44N., R. 2E., Klondike Quarry, St. Charles Co.
83	0.14	99.57	0.085	0.065	0.08	0.09	100.03	Gray	Sec. 1, T. 45N., R. 3W., Warren Co.
91	0.15	99.64	0.097	0.063	0.03	0.01	99.99	White with slight gray tint	Sec. 2, T. 46N., R. 6W., Americus, Montgomery Co.
93	0.18	99.54	0.07	0.13	0.06	tr	99.98	White with pale buff tint	Sec. 36, T. 47N., R. 6W., Montgomery Co.
109	0.72	97.60	0.10	0.20	1.02	0.22	99.86	White with pale buff tint	S. E. ¼, Sec. 27, T. 40N., R. 6E., Jefferson Co.
116	0.14	99.54	0.10	0.20	0.02	0.02	100.02	Very pale buff tint	N. E. ¼, N. E. ¼, Sec. 10, T. 38N., R. 7E., Ste. Genevieve Co.
*120	0.20	99.50	0.067	0.093	0.12	tr	100.00	White with very pale buff tint	Sec. 26, T. 37N., R. 8E., Ste. Genevieve Co.
133	0.16	99.72	0.06	0.02	0.02	tr	99.98	White	N. E. ¼, N. E. ¼, Sec. 15, T. 36N., R. 10E., Perry Co.
*220	0.18	99.30	0.09	0.09	0.20	0.10	99.96	White, faint yellow and green spots	Sec. 20, T. 40N., R. 6E., Jefferson Co.
226	0.70	99.00	0.057	0.183	0.04	tr	99.98	White, with very faint buff tint	S. W. ¼, Sec. 19, T. 30N., R. 13E., Cape Girardeau Co.
241	0.24	99.36	0.10	0.34	None	tr	100.04	Very faint buff tint	Holt Summit, Callaway Co.
15	0.35	98.56	0.43	0.56	0.01	0.07	99.98	Very red	N. E. ¼, Sec. 11, T. 32N., R. 11E., Cape Girardeau Co.
29	0.35	98.64	0.297	0.573	0.03	0.09	99.98	Deep buff	Sec. 17, T. 31N., R. 12E., Cape Girardeau Co.
32	0.50	97.59	0.243	1.037	tr	0.40	99.77	Decided greenish shade	Pittsburgh Plate Glass Company's Quarry, Crystal City—"Mud Seam."
33	0.12	99.51	0.14	0.16	0.09	0.02	100.04	Pale reddish yellow	Pittsburgh Plate Glass Company's Quarry, Crystal City, Discarded red layer.
46	0.38	98.62	0.21	0.47	0.23	0.05	99.96	Deep gray to buff	N. ½, N. W. ¼, Sec. 29, T. 44N., R. 2E., Franklin Co.
59	1.09	95.98	0.80	1.46	0.29	0.18	99.80	Deep red	S. W. ¼, Sec. 28, T. 42N., R. 2E., Jefferson Co.
70	0.84	96.65	0.94	1.17	0.19	0.10	99.89	Deep reddish brown	N. W. ¼, N. W. ¼, Sec. 2, T. 49N., R. 2E., Lincoln Co.

The foregoing analyses represent unwashed samples, which in the case of all the white sands were chosen carefully to represent as nearly as possible the average composition of the ledge from which they were taken. They were chosen to represent what is believed to be favorable glass sands. The red samples were chosen to illustrate the ferruginous phases of the formation. Of course, the few inches of moss-covered and stained surface were removed. Below is also given a table of previously published analyses of St. Peter sand from Missouri, and following that is a list of published analyses of St. Peter sand from other States. The latter list is given to emphasize the wide area over which this remarkable purity is known to be characteristic of the formation.

Previously published St. Peter analyses from Missouri.

No.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss on ignition, H_2O, CO_2, and organic matter.
A.	99.97	0.03	....	....	....	.....
B.	99.69	....	....	0.31		.....
C.	99.57	....	0.43	....	....	.....
D.	99.68	0.18	trace	....	....	0.14
E.	99.839	....	0.0014	....	....	0.154
F.	99.55	0.33	trace	0.08	....	0.015
G.	99.52	0.16	0.07	....	....	.....
H.	99.03	0.40	FeO 0.13	0.29	0.11	0.44
I.	99.20	0.56		trace	0.20	0.08
J.	99.405	0.210	0.075	0.072	0.068	0.170

For authorities for the above analyses, see table on page 124.

List of authorities for analyses of St. Peter sandstone in Missouri.

No.	Location.	Operator.	Authority.	Author's Remarks.
A	Klondike, St. Charles Co.	Tavern Rock Sand Co.	Regis Chauvenet and Co., cited in Mineral Resources of United States, 1911.	Probably a very carefully selected sample, possibly washed.
B	Near Pacific, Jefferson Co.	Missouri Silica Company.	Regis Chauvenet and Co., cited in Mineral Resources of United States, 1911.	The entire absence of iron and alumina probably indicates a washed sample.
C	Near Pacific, St. Louis Co.	Pacific Glass Sand Co.	Analysis furnished by the company in a personal letter.	Fe_2O_3 probably includes Al_2O_3, and SiO_2 was probably determined by difference.
D	Grays Summit, Franklin Co.	Grays Summit White Sand Co.	Analysis furnished by the company in a personal letter.	
E	Grays Summit, Franklin Co.	White Sand Co. of Missouri.	John F. Wixford, cited in Mineral Resources of United States, 1911.	Probably washed or very carefully selected.
F	Near Silex, Lincoln Co.		Regis Chauvenet and Co., reported in Mo. Geol. Survey, 1872.	
G	Jackson, Cape Girardeau Co.	Jackson Lime and Quarry Co.	Geo. Steiger, Mineral Resources of United States, 1911.	Company reported out of business, not possible to ascertain locality where sample was secured.
H	Versailles, Morgan Co.		Geo. Steiger, Mineral Resources of United States, 1911.	Identity of sandstone uncertain. Reported as Roubidoux. May be St. Peter.
I	Near Pacific, St. Louis Co.	Pacific Glass Sand Co.	Pacific Plate Glass Company, reported in Mineral Resources of United States, 1911.	
J	Crystal City, Jefferson Co.	Pittsburgh Plate Glass Company.	F. Gelsthorp, Chief Chemist, furnished in personal letter.	Average of several analyses of unwashed, quarry-run sand.

Analyses of St. Peter sandstone from other states.

No.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss on ignition,= $CO_2 + H_2O$ + organic matter.	Other constituents.
A.....	98.85	0.46	0.095	0.21	0.00	0.114	0.27 (Alkalies)
B.....	99.45	0.30		0.13	Tr.		
C.....	99.89	0.051	Tr.	0.00	0.01		
D.....	99.89	0.051	....	0.00	0.01		
E.....	99.576	0.283	0.0903	0.0197	0.002		

List of authorities for analyses of St. Peter sandstone in other States.

No.	Location.	Operator.	Authority.
A....	Clayton, Iowa.....	.....	Iowa Geol. Survey, Vol. 1, p. 25.
B....	Ottawa, Lasalle Co., Ill.....	Ottawa Silica Co..	U. S. Min. Res., 1911.
C....	South Ottawa, Lasalle Co., Ill.....	U. S. Silica Co....	U. S. Min. Res., 1911.
D....	Wedron, Lasalle Co., Ill....	Wedron White Sand Co.....	U. S. Min. Res., 1911.
E....	Utica, Lasalle Co., Ill.....	E. J. Reynolds and Co.....	U. S. Min. Res., 1911.

Occasional slightly ferruginous layers, showing a distinctly reddish or yellowish tint, are to be seen within massive deposits of almost pure and very white sandstone. One of these ferruginous layers from the Pittsburgh Plate Glass Company's quarry at Crystal City shows the following composition (Sample No. 33.)

Analysis of ferruginous layer of St. Peter from Crystal City.

SiO_2	99.51
Al_2O_3	0.16
Fe_2O_3	0.14
CaO	0.09
MgO	0.02
Ignition loss	0.12
	100.04

Thin greenish layers are also frequently seen in the quarries or along the freshly exposed face of cliffs of the purer sandstone. The green stain is in the clay, as washing yields a perfectly white sand. The color is probably due to a very small proportion of chlorite in the clay or is possibly due to organic matter. A sample (No. 32) from such a layer, also from the Crystal City

quarry of the Pittsburgh Plate Glass Company, was analysed with the following results:

Analysis of clay seam at Crystal City.

SiO_2	97.59
Al_2O_3	1.037
Fe_2O_3	0.243
CaO	tr.
MgO	0.40
Ignition	0.50
	99.77

Where the ledge has long been exposed to weathering and the leaching down of the impurities from the soil above, the sandstone is much less pure, showing especially the introduction of iron oxide. Analyses of five typically ferruginous samples of this sort show an average of 0.535 per cent iron. In all instances where red samples were taken, a crust of an inch or two was removed before the sample was selected, in order to get rid of the extremely ferruginous surface. The red samples chosen represent a fair average of the ferruginous phases of the sandstone. (See table, p. 122.)

SIZE AND UNIFORMITY OF GRAIN.

In many previous discussions, emphasis has been placed on the remarkable uniformity of the St. Peter sandstone in the size of grain. In order to test these statements, a large number of screening tests have been made on this and other sands, and the results are summed up in accompanying tables (p. 126). Each tabulation gives the computed effective size and uniformity coefficient. An explanation of the meaning of these is to be found on pp 11-16.

No.	Passing each sieve and retained on the next.									
	200	150	100	90	80	70	60	50	40	30
4	2.66	1.42	8.66	7.13	3.82	16.64	22.64	29.39	5.94	1.70
7	1.08	0.75	5.08	7.29	4.10	15.78	22.25	28.10	10.40	4.75
11	0.64	0.24	4.88	5.65	2.50	5.93	8.69	36.03	32.31	3.10
14	4.04	0.84	6.24	8.72	3.73	10.29	12.49	19.39	15.39	10.03
15	0.44	0.12	2.12	4.45	2.18	8.81	12.77	27.32	25.46	12.71
24	2.37	0.66	7.20	10.95	5.43	12.95	10.95	18.26	18.28	9.19
28	0.57	0.19	2.60	3.74	1.37	4.47	6.12	20.18	31 41	22.81
32	2.17	0.42	3.03	3.49	1.63	4.82	8.32	22.52	31.07	20.35
33	0.31	0.09	0.54	0.58	0.38	0.97	2.39	13.40	45.14	33.94
34	0.56	0.37	5.45	16.52	3.63	17.47	15.37	25.40	13.25	1.91
57	1.00	0.82	14.78	17.65	5.72	13.35	11.11	13.89	10.62	7.98
70	0.00	0.06	0.19	0.70	0.59	2.76	7.21	24.70	29.90	27.25
76	0.38	0.31	5.66	8.69	4.22	10.39	14.72	24.11	17.42	10.39
77	0.75	0.81	19.60	11.33	2.69	5.32	5.19	13.41	18.72	16.02
78	0.37	0.12	1.94	3.50	1.82	7.75	10.89	27.14	22.58	15.20
82	2.16	1.56	16.91	19.87	7.29	18.56	16.49	11.53	3.90	1.47
91	0.13	0.12	4.34	11.62	5.00	15.74	18.24	20.86	11.00	8.20
93	0.20	0.14	4.54	8.38	4.54	12.68	16.28	20.71	13.49	11.10
109	0.44	0.25	4.26	5.96	3.01	10.23	8.37	23.17	28.69	13.43
111A	0.38	0.32	4.92	6.74	2.89	9.26	11.67	29.89	25.49	8.06
116	0.19	0.25	4.59	5.64	2.64	8.19	12.72	30.35	26.60	7.77
133	2.84	0.58	2.28	2.01	1.37	4.63	19.61	30.71	20.61	8.59
137	6.54	1.15	4.61	3.94	1.83	5.81	10.30	21.80	18.04	14.01
190	1.19	0.63	7.31	7.68	3.78	9.15	11.41	25.50	23.27	9.20
191	0.08	0.12	3.06	6.35	3.67	10.98	13.81	27.40	25.26	8.28
192	0.18	0.18	5.72	10.56	5.33	15.20	18.03	27.26	14.13	3.15
202	0.49	0.27	2.53	2.72	1.07	3.29	4.73	12.25	33.55	30.20

No.	Passing each sieve and retained on the next.												Retained on No. 10
	200	150	100	90	80	70	60	50	40	30	20	10	
217	0.45	0.12	2.15	0.49	1.19	3.13	4.56	6.35	4.30	7.90	8.76	19.96	40.60
199	0.72	0.11	1.06	1.96	1.11	4.44	7.22	26.19	39.40	12.08	5.59	0.12	.....
195	0.15	0.13	3.31	6.11	7.25	9.42	16.15	31.29	19.45	6.11	0.63	.....	.....
89	0.76	0.19	0.63	1.84	1.25	6.22	15.84	41.74	26.89	3.76	0.88	.....	.....
96	0.54	0.09	0.53	2.42	1.90	9.92	21.95	34.55	20.57	6.57	0.96	.....	.....
205	1.23	0.03	12.13	1.69	3.20	13.79	22.13	21.53	16.83	7.21	0.23	.....	.....
88	1.46	0.69	12.40	15.18	5.61	15.66	19.22	20.01	4.78	3.35	1.64	.....	.....
97	1.20	0.25	1.84	2.73	1.33	8.44	7.68	34.90	28.41	11.37	1.85	.....	.....
103	1.83	0.75	4.91	15.49	2.83	17.66	21.98	26.35	7.49	0.85	0.13	.....	.....
105	0.21	0.12	2.20	9.83	3.52	10.39	12.48	34.07	25.00	2.08	0.10	.....	.....
106	8.23	1.26	4.60	4.66	2.99	12.00	15.40	34.88	12.65	3.83	.....	.....	.....
20	8.08	2.72	26.46	11.28	4.10	12.06	6.19	18.66	9.32	1.13	.....	.....	.....
23	1.18	0.25	2.32	2.46	1.17	4.92	6.99	34.65	38.30	7.44	0.31	.....	.....
135	4.71	0.75	4.41	4.35	1.88	6.46	13.12	34.29	11.87	8.69	9.47	.....	.....
131	4.24	1.71	16.89	18.61	9.93	21.70	16.10	8.80	1.58	0.44	.....	.....	.....
2146	0.00	0.09	1.67	7.35	3.94	17.70	21.24	25.69	13.28	7.11	1.93	.....	.....
120	0.15	0.15	5.31	8.31	5.06	10.82	15.09	22.19	18.62	11.12	3.18	.....	.....
12	0.89	0.12	0.95	0.07	0.27	0.57	1.26	7.20	31.70	50.20	6.61	0.11	.....

NOTE—nd.=Not determined

SCREEN TESTS ON ST. PETER SANDSTONE.

Retained on		Total passing each sieve.											
20	10	No. 10	200	150	100	90	80	70	60	50	40	30	20	10
.....	.....	.....	2.66	4.08	12.74	19.87	23.69	40.33	62.97	92.36	98.30	100.00	100.00	100.00
0.42	.....	.....	1.08	1.83	6.88	14.17	18.27	34.05	56.30	84.40	94.80	99.55	99.97	99.97
0.03	.....	.....	0.64	0.88	5.76	11.41	13.91	19.84	28.53	64.56	96.87	99.97	100.00	100.00
8.84	.....	.....	4.04	4.88	11.12	19.84	23.57	33.86	46.35	65.74	81.13	91.16	100.00	100.00
3.62	.....	.....	0.44	0.56	2.68	7.13	9.31	18.12	30.89	58.21	83.67	96.38	100.00	100.00
3.76	.....	.....	2.37	3.03	10.23	21.18	26.61	39.56	50.51	68.77	87.05	96.24	100.00	100.00
6.54	.....	.....	0.57	0.76	3.36	7.10	8.47	12.94	19.06	39.24	70.65	93.46	100.00	100.00
2.18	.....	.....	2.17	2.59	5.62	9.11	10.74	15.56	23.88	46.40	77.47	97.82	100.00	100.00
2.26	.....	.....	0.31	0.40	0.94	1.52	1.90	2.87	5.26	18.66	63.80	97.74	100.00	100.00
0.04	.....	.....	0.56	0.96	6.41	22.93	26.56	44.03	59.40	84.80	98.05	99.96	100.00	100.00
3.14	.....	.....	1.00	1.82	16.60	34.25	39.97	53.32	64.43	78.32	88.94	96.82	99.96	99.96
6.64	.....	.....	0.00	0.06	0.25	0.95	1.54	4.30	11.51	36.21	66.11	93.36	100.00	100.00
3.71	.....	.....	0.38	0.69	6.35	15 04	19.26	29.65	44.37	68.48	85.90	96.28	99.99	99.99
6.16	.....	.....	0.75	1.56	21.16	32.49	35.18	40.50	45.69	59.10	77.82	93.84	100.00	100.00
8.69	.....	.....	0.37	0.49	2.43	5.93	7.75	15.50	26.39	54.53	77.11	92.31	100.00	100.00
0.26	.....	.....	2.16	3.72	20.63	40.50	47.79	66.35	82.84	94.37	98.27	99.74	100.00	100.00
4.75	.....	.....	0.13	0.25	4.59	16.21	21.21	36.95	55.19	76.05	87.05	95.25	100.00	100.00
7.94	.....	.....	0.20	0.34	4.88	13.26	17.80	30.48	46.76	67.47	80.96	92.06	100.00	100.00
2.19	.....	.....	0.44	0.69	4.95	10.91	13.92	24.15	32.52	55.69	84.38	97.81	100.00	100.00
0.38	.....	.....	0.38	0.70	5.62	12.36	15.25	24.51	36.18	66.07	91.56	99.72	100.00	100.00
1.06	.....	.....	0.19	0.44	5.03	10.67	13.31	21.50	34.22	64.57	91.17	98.94	100.00	100.00
6.77	.....	.....	2.84	3.42	5.70	7.71	9.08	13.71	33.32	64.03	84.64	93.23	100.00	100.00
11.97	.....	.....	6.54	7.69	12.30	16.24	18.07	23.88	34.18	55.98	74.02	88.03	100.00	100.00
0.88	.....	.....	1.19	1.82	9.13	16.81	20.59	29.74	41.15	66.65	89.92	99.12	100.00	100.00
0.99	.....	.....	0.08	0.20	3.26	9.61	13.28	24.26	38.07	65.47	90.73	99.01	100.00	100.00
0.12	.....	.....	0.18	0.36	6.08	16.64	21.97	37.17	55.20	82.46	96.59	99.74	99.86	99.86
8.87	0.03	.....	0.49	0.76	3.29	6.01	7.08	10.37	15.10	27.35	60.90	91.10	99.97	100.00

SCREEN TESTS ON SANDSTONE OTHER THAN ST. PETER.

Total passing each sieve.												Effective size.	Uniformity coefficient.	Sp
200	150	100	90	80	70	60	50	40	30	20	10			
0.45	0.57	2.72	3.21	4.40	7.53	12.09	18.44	22.75	30.65	39.41	59.37	0.21	8.00	
0.72	0.83	1.89	3.85	4.96	9.40	16.62	42.81	82.21	94.29	99.88	100.00	0.20	1.55	
0.15	0.28	3.59	9.70	16.95	26.37	42.52	73.81	93.26	99.37	100.00	100.00	0.15	1.65	
0.76	0.95	1.58	3.42	4.67	10.89	26.73	68.47	95.36	99.12	100.00	100.00	0.18	1.44	
0.54	0.63	1.16	3.58	5.48	15.40	37.35	71.90	92.47	99.04	100.00	100.00	0.18	1.44	
1.23	1.26	13.39	15.08	18.28	32.07	54.20	75.73	92.56	99.77	100.00	100.00	0.13	1.85	
1.46	2.15	14.55	29.73	35.34	51.00	70.22	90.23	95.01	98.36	100.00	100.00	0.13	1.54	
1.20	1.45	3.29	6.02	7.35	15.79	23.47	58.37	86.78	98.15	100.00	100.00	0.18	1.60	
1.83	2.58	7.49	22.98	25.81	43.47	65.45	91.80	99.29	100.14	100.27	100.27	0.14	1.50	
0.21	0.33	2.53	12.36	15.88	26.27	38.75	72.82	97.82	99.90	100.00	100.00	0.18	1.82	
8.23	9.49	14.09	18.75	21.74	33.74	49.14	84.02	96.67	100.50	100.50	100.50	0.11	2.27	
8.08	10.80	37.26	48.54	52.64	64.70	70.89	89.55	98.87	100.00	100.00	100.00	0.10	1.88	
1.18	1.43	3.75	6.21	7.38	12.30	19.29	53.94	92.24	97.68	99.99	99.99	0.18	1.61	
4.71	5.46	9.87	14.22	16.10	22.56	35.68	69.87	81.84	90.53	100.00	100.00	0.14	1.86	
4.24	5.95	22.84	41.41	51.34	73.04	89.14	97.94	99.52	99.96	99.96	99.96	0.12	1.45	
0.00	0.09	1.76	9.11	13.05	30.75	51.99	77.68	90.96	98.07	100.00	100.00	0.16	1.49	
0.15	0.30	5.61	13.92	18.98	29.80	44.89	57.08	75.70	86.82	100.00	100.00	0.14	1.75	
0.89	1.01	1.96	2.03	2.30	2.87	4.13	11.33	43.03	93.27	99.84	100.00	0.28	1.39	

ct- e.	Uniformity coefficient.	Locality.
33	1.61	Sec. 25, T. 35N., R. 10E., Perry Co.
45	1.55	Sec. 3, T. 35N., R. 10E., Perry Co.
50	1.83	Sec. 5, T. 34N., R. 11E., Perry Co.
30	2.00	Sec. 6, T. 33N., R. 11E., Bollinger Co.
80	1.63	Sec. 11, T. 32N., R. 11E., Cape Girardeau Co.
40	1.80	Sec. 4, T. 31N., R. 12E., Cape Girardeau Co.
80	1.92	Sec. 19, T. 30N., R. 13E., Cape Girardeau Co.
60	1.96	Pittsburgh Plate Glass Co., Crystal City.
50	1.48	Pittsburgh Plate Glass Co., Crystal City.
40	1.56	Pittsburgh Plate Glass Co., Crystal City.
20	1.66	Sec. 18, T. 42N., R. 4E., Jefferson Co.
10	1.67	Sec. 2, T. 49N., R. 2E., Lincoln Co.
50	1.75	Sec. 33, T. 51N., R. 1W., Lincoln County.
20	2.18	Tavern Rock Co., Klondike, St. Charles Co.
80	1.72	Tavern Rock Co., Klondike, St. Charles Co.
30	1.43	Sec. 32, T. 46N., R. 2W., Warren Co.
50	1.58	Sec. 2, T. 46N., R. 6W., Montgomery Co.
50	1.71	Sec. 24, T. 47N., R. 6W., Montgomery Co.
50	2.00	Sec. 27, T. 40N., R. 6E., Jefferson Co.
50	1.82	Washed sand, Pittsburgh Plate Glass Co., Crystal City.
50	1.81	Sec. 10, T. 38N., R. 7E., Ste. Genevieve Co.
80	1.50	Sec. 14, T. 36N., R. 10E., Perry Co.
30	2.31	Sec. 31, T. 36N., R. 12E., Perry Co.
40	1.84	Pacific Glass Sand Co., Pacific.
50	1.74	Pacific Glass Sand Co., Pacific, Washed sand.
40	1.63	Pacific Glass Sand Co., Pacific, Washed sand.
70	2.23	Ottawa, Ill.

Per cent voids.	Weight per cu. ft.	Weight per cu. yd.	Per cent dirt.	Horizon and locality.
37.3	101.88	2748	4.7	Lamotte sandstone, Ste. Genevieve Co.
49.3	83.66	2259	4.8	Roubidoux sandstone, Meramec Springs, Phelps Co.
48.0	85.60	2313	Trace	Roubidoux sandstone, Ava, Douglas Co.
nd	nd	nd	nd	Pennsylvanian sandstone, Montgomery Co.
nd	nd	nd	nd	Pennsylvanian sandstone, Montgomery Co.
nd	nd	nd	nd	Pennsylvanian sandstone, Arcola.
nd	nd	nd	nd	Jefferson City sandstone, Montgomery Co.
nd	nd	nd	nd	Jefferson City sandstone, Jefferson Co.
nd	nd	nd	nd	Jefferson City sandstone, Jefferson Co.
nd	nd	nd	nd	Jefferson City sandstone, Jefferson Co.
nd	nd	nd	nd	Jefferson City sandstone, Jefferson Co.
nd	nd	nd	nd	Joachim sandstone, Cape Girardeau Co.
nd	nd	nd	nd	Joachim sandstone, Cape Girardeau Co.
nd	nd	nd	nd	Aux Vases sandstone, McBride, Perry Co.
nd	nd	nd	nd	Chester sandstone, St. Marys, Ste. Genevieve Co.
nd	nd	nd	nd	Commerce sandstone, Commerce, Scott Co.
nd	nd	nd	nd	Everton sandstone, River aux Vases, Ste. Genevieve Co.
48.4	84.40	2280	5.3	Roubidoux sandstone, Rolla, Phelps County.

From these tables, it will be seen that the effective size of the St. Peter sand samples tested ranges between 0.12 mm. and 0.25 mm. with an average of 0.154 mm. for 26 specimens. These specimens represent the entire area of outcrop in this State. Eighteen other samples of local sandstones, representing eight different formations ranging in age from Cambrian to Tertiary show effective size varying between 0.10 mm. and 0.28 mm. with an average of 0.158 mm. The difference is entirely inappreciable either as to average or extreme range.

In uniformity coefficient, the same 26 samples of St. Peter give a maximum of 2.31 and a minimum of 1.43, with an average of 1.84. The eighteen samples of other sandstones show a maximum of 2.27 (excluding No. 217, which is really a conglomerate), a minimum of 1.39, and an average of 1.65. The latter comparison shows that the St. Peter sandstone has a greater range of size, and averages less uniform than the other formation sampled.

This should be sufficient to show that the factor of uniformity has been heretofore greatly overestimated in describing the St. Peter formation.

Except for a thin layer of conglomeratic material at the very base of the sandstone, the formation seems to be absolutely free of pebbles; and with a few rare exceptions, the pebbles in this basal conglomerate are so sharply angular that the material appears more like a breccia than like a true conglomerate.

DEGREE OF ROUNDING.

Much emphasis has been laid on the very perfect degree of rounding of the grains of the St. Peter sandstone. It is true that samples of this formation when examined and compared with samples of other sands give a very decided impression of greater rounding and polish of grain, and it is also undoubtedly true that, as a whole, the St. Peter grains average a better degree of rounding than do those of many other sandstones.

Nevertheless, it is quite probable that this characteristic has also been over emphasized. In support of this contention, the following facts are presented. The writer had an assistant prepare a number of samples of sand both from the St. Peter and from other formations to be examined under the microscope with a low power objective. The assistant changed the samples and the writer attempted to recognize the St. Peter by its rounding. Frequent errors were made, both in calling other sands

the St. Peter and in thinking the St. Peter was a sample of some other formation. Somewhat more than half the determinations were correct. Care was taken to select only white samples of other sandstones so that color would give no aid in the determination.

COLOR.

Fresh exposures of the St. Peter are characteristically white. This is almost invariably true where the formation is exposed in recent workings. Along steep cliff-like outcrops the formation also usually appears white, or, if somewhat weathered, a light gray. The white color seems to be very uniform from top to base of the formation. If any difference exists it would be that in perfectly fresh exposures the base of the formation is even whiter than the top. Of course, this applies only to the typical formation. The basal conglomerates and residual Jefferson City soils are usually iron-stained. The face of white exposures frequently shows thin beds usually from 1 to 4 inches thick of reddish or brownish sand. Quarrying often shows such ferruginous bands to be rather persistent. An analysis of such a bed (Sample No. 33) from the Pittsburgh Plate Glass Company's quarry at Crystal City was made, and the results are given below. It will be seen that the amount of iron necessary to produce this discoloration is small.

Analysis of red layer of St. Peter sandstone from Crystal City.

SiO_2	99.51
Fe_2O_3	0.14
Al_2O_3	0.16
CaO	0.09
MgO	0.02
Ignition loss	0.12
	100.04

Fresh white exposures also sometimes show 1 to 4-inch beds of a pale green color, called by quarrymen "mud seams." An analysis (Sample No. 32) showing the composition of the "mud seam" which forms the roof of the mine at the Pittsburgh Plate Glass Company's quarry at Crystal City is given on page 126. The sample runs high in alumina, and it is believed the color is due to a small amount of chlorite in the clay. By washing the sand and decanting off the finer material, the sand washes perfectly white, showing that the green coloring matter is in the clay.

Although fresh exposures of the sandstone are characteristically white, low lying and long weathered outcrops are frequently highly ferruginous. There are abundant evidences, however, that in most cases the iron of the red and yellow phases of the formation is leached in from overlying ferruginous soils and is not part of the original composition of the sandstone. At several of the quarries the sandstone, although very white where freshly quarried or where lying beneath a protecting cover of Joachim, is highly ferruginous where exposed in natural outcrop, especially where the exposure is low and flat and partly covered with red soil. At the Tavern Rock Sand Company's quarries at Pacific and Klondike and also at the Enterprise Sand and Mining Company's quarry between Herculaneum and Festus, the surface of the natural exposures of the sandstone is remarkably ferruginous along portions of the top of the quarry where the limestone cover is absent, and where the loess constitutes the only overburden.

During the course of the field work for this report, it was repeatedly noted that in deeply dissected regions where cliffs or very steep slopes prevail, there is a much larger proportion of white outcrop, while in little dissected regions where the slopes were gentle, the sandstone is dominantly red. This is believed to be due to the fact that the cliffs and steeper slopes are more protected from the leaching down of iron from an overburden of ferruginous soil. In Perry and Cape Girardeau counties, particularly where dissection is very incomplete and where gentle slopes prevail and cliffs are rare, there are few places where the sandstone is white. Throughout most of this region the St. Peter is so ferruginous as to seem like a totally different formation.

Because the basal portion of the St. Peter has been longer exposed to erosion and because it is more frequently seen in low, flat exposures, it seems to be the more ferruginous, while the upper portion, recently exposed, or even yet capped with protecting Joachim, seems whiter. This appearance is probably deceptive, and where seen in perfectly fresh cliff exposures where a full section can be viewed at once, the lower beds are seen to be as white as the upper.

That the discoloration is a superficial phenomenon even in the region where the formation seems so iron-stained is clearly shown by the fact that the St. Peter cuttings from a deep well in Perryville, where there is a protective cover of over 200 feet

of Joachim and Plattin, are as white as the best sand from the same formation elsewhere, although the natural outcrops along the belt about a mile to the southwest are highly ferruginous.

A well on the farm of D. B. Trower in sec. 10, T. 49 N., R. 2 E., in Lincoln county shows the sandstone red at a depth of 117 feet. This, however, is practically on the Cap au Gres fault. The sandstone is much shattered, and it is possible that the deep discoloration is due to leaching down of ferruginous solutions along the zone of faulting and brecciation.

CEMENTATION.

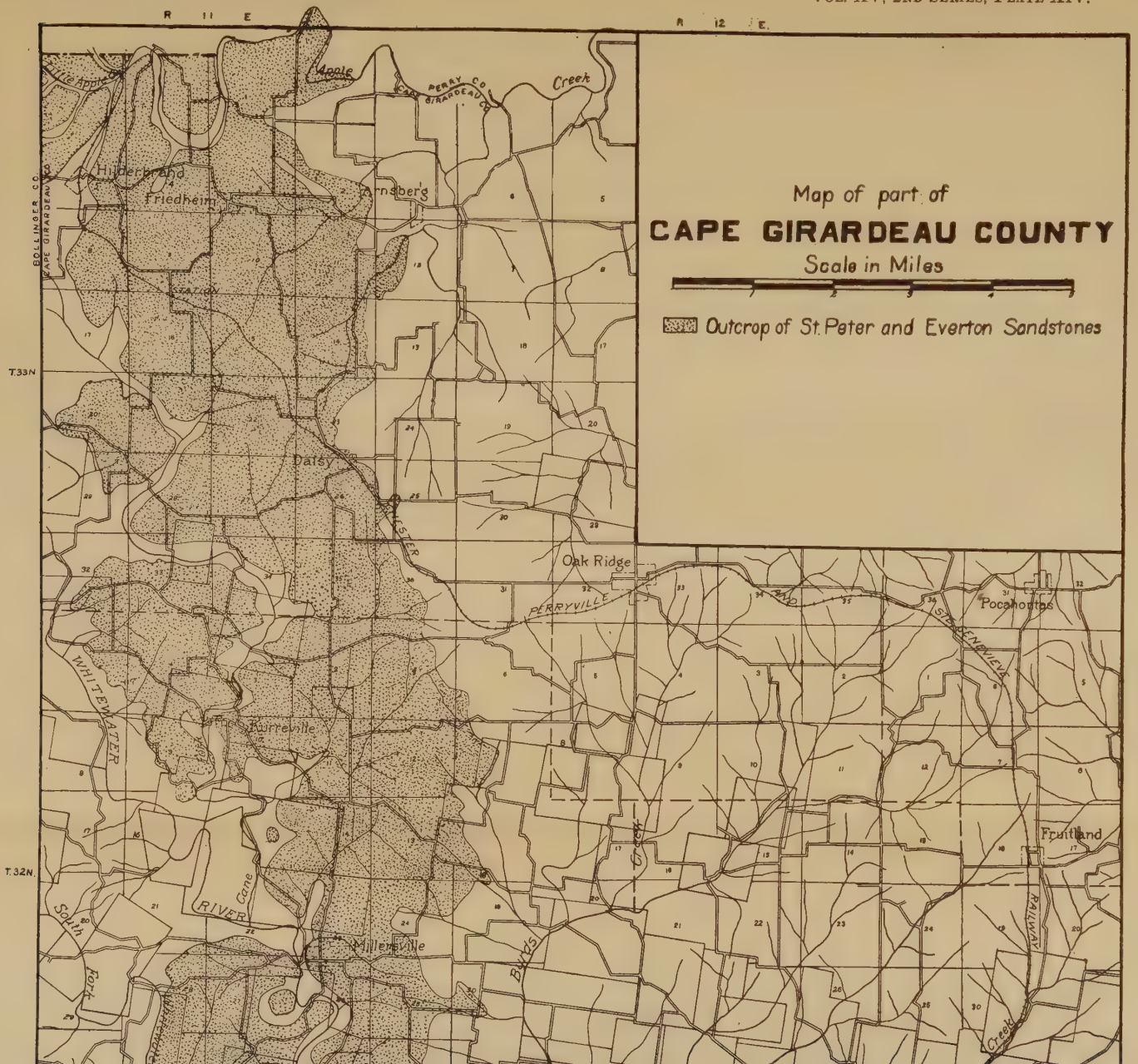
In general, the St. Peter is a very soft, friable sandstone. Frequently it is so incoherent that it crumbles completely under a stroke of the hammer, and can usually be readily crushed in the fingers.

There are, however, rather marked differences in the cementation of the formation. In the quarry of the Pittsburgh Plate Glass Company at Crystal City, the sandstone needs no crushing, the washing being sufficient to cause it to crumble into its constituent grains, while at the quarry of the Enterprise Sand and Mining Company only about two miles distant, it is necessary to use a hammer mill to crush the rock, and at the Tavern Rock Sand Company's quarry at Klondike, some of the whitest sand is even almost quartzitic.

In the vicinity of the zone of faulting already described, in northern and eastern Perry County, the sandstone becomes decidedly quartzitic, extremely hard, and very much veined. Plate XV, A shows veining in the sandstone about a mile west of Lithium in the NE. ¼ NE. ¼ sec. 15, T. 36 N., R. 10 E., and Plate XV, B the veining in the formation north of Menfro in the NE. ¼ sec. 31, T. 36 N., R. 12 E.

The superficially ferruginous phases of the St. Peter are frequently much more firmly cemented than are the whiter portions of the formation, though this is not always the case. This surface induration is somewhat analogous to casehardening, except that the ferruginous cement in this instance is undoubtedly leached down from above and introduced into the sandstone from without, instead of being brought from the interior out and left by evaporation, as in true casehardening. It is not at all uncommon to see the surface of the rock for several inches cemented into a hard brown mass, while the interior is very friable and almost white.

River
Creek
Hubble
Goose
Creek
C.P.& STA.G.R.
JACKSON
Burfordville
Gravelhill
T.31N.
Creek
Burfords
Creek
Tilsit
Granny Creek
Gordonville
Houck
Randall
Creek
WHITEWATER
T30N.
ST. LOUIS
Crowfield
IRON MOUNTAIN
AND SOUTHERN RY.
Whitewater
ST. LOUIS
Dutchtown
Hubble
Creek
Nash
ST.L.& S.F.R.R.
ST.L.& S.F.R.R.
Allenville
Cousinville
RIVER
Creek
BOLLINGER CO.
CAPE GIRARDEAU CO.


R 11 E
R 12 E.
Map of part of
CAPE GIRARDEAU COUNTY
Scale in Miles
Outcrop of St. Peter and Everton Sandstones
T.33N.
T.32N.
Hilderbrand
Friedheim
Daisy
Oak Ridge
Pocahontas
Fruitland
Millersville
Burfordville
PERRYVILLE
WHITEWATER
RIVER
Cane
South Fork
Creek
BOLLINGER CO.
CAPE GIRARDEAU CO.
PERRY CO.
CAPE GIRARDEAU CO.

DETAILED COUNTY DESCRIPTIONS.

CAPE GIRARDEAU COUNTY.

Distribution. — About 70 square miles, or nearly one-seventh of the area of this County, is immediately underlain by the St. Peter sandstone which extends through the western half of the County, from Dutchtown at the edge of the Mississippi lowland to the extreme northwest corner. The belt trends about N. 20° W., and varies from two to six miles in width. Its eastern border passes about a mile east of Dutchtown, through Gordonville, about two miles west of Jackson, two miles west of Oak Ridge, a few rods to the east of Daisy, and crosses Apple Creek into Perry County about three miles and a half east of the west line of Cape Girardeau County. The western boundary in general lies from one-half to two miles east of Whitewater River, although in the vicinity of Millersville a considerable outlier of the sandstone lies west of the main Whitewater in the angle between it and the South Fork. The accompanying county map (Pl. XIV) shows the detailed distribution of the formation.

Outcrops. — Although the sandstone occupies a broader belt in this County than it does elsewhere in the State, it probably has a smaller actual exposure than in any other county located on the belt except St. Louis County. This is due to the fact that the formation outcrops along a very slightly dissected, almost prairie-like ridge east of Whitewater River, over which there is a deep mantle of residuum and loess. Most of the outcrops which do occur are low and flat, and are found in the bottoms of shallow creeks or ravines. The best cliffs of the formations are exposed along Apple Creek in the northwest corner of the County, on Cain and Byrd's Creeks just west of Jackson, and along the escarpment that overlooks the Mississippi flood plain in the vicinity of Dutchtown. South of Jackson, outcrops are especially scarce, owing to a heavy cover of loess which rendered the mapping of contacts in that vicinity difficult and uncertain.

General nature of the formation.—Throughout the County, the formation consists of a moderately fine-grained, very friable sandstone with well-rounded grains. Over most of its extent it is very ferruginous on the outcrop, being a deep reddish or yellowish-brown color. An analysis of the ferruginous sandstone was made in order to determine how much iron is

required to give the characteristic red color so prevalent over the County.

The sample analysed (No. 15) was taken from a low ledge at the road intersection near the center of the NE. ¼ sec. 11, T. 32 N., R. 11 E., and is as nearly a fair average of the sandstone in the County as it was possible to select. The analysis shows 0.43 per cent iron oxide, and 0.56 per cent alumina (see table, p. 122.)

Thickness.—Little evidence is available as to the thickness of the formation in this County. In the older reports,[1] it is given as 100 feet. Owing to conditions already described (p. 113-114), it has been very difficult to make any satisfactory estimate. Wells at Jackson are reported to have penetrated 126 and 147 feet of the sandstone and to be bottomed in the formation. This may include part of the Everton. A well at Cape Girardeau penetrated 60 feet of white sandstone, presumably the St. Peter, passing entirely through the formation.

Favorable localities.—In this County only three localities were noted that offer even the remotest possibility of producing glass sand, and of these only one seems to be especially encouraging. The first is along Apple Creek, in secs. 2, 3, 4 and 5, T. 33 N., R. 11 E. In this vicinity the formation occurs in rather steep, massive bluffs along the creek and some of its smaller tributaries within a short distance of the Cape Girardeau and Northern Railroad and under topographic conditions fairly well suited to quarrying. Wherever seen in the region in question, however, the sand was altogether too ferruginous on the surface of the outcrop to be of any value for a glass sand, but in view of the fact that at many localities the ferruginous discoloration, though extreme, has proved to be only a superficial phenomenon limited to a few inches or feet at the surface of the formation, it is possible that blasting in some of these cliffs might show up white sand of value. The prospects here, however, are considered to be decidedly unfavorable.

The second of these regions lies just to the west of Jackson, where the dissection of the belt by Cain Creek and Byrd's Creek gives rather abundant outcrops and steep slopes. The United States Geological Survey[2] reports the following analysis from Jackson of a sample submitted by the Jackson Lime and Quarry Company.

---

[1]Shumard, B. F., Reports on the Geological Survey of the State of Missouri, p. 268, 1873.
[2]Buchard, E. F., Mineral Resources of the United States for 1911, pt. 2, p. 632.

A. Veining in the St. Peter sandstone near the large fault just west of Lithium, Perry County.

B. Veining in the St. Peter sandstone near the large fault just north of Menfro, Perry County.

A. Cliff of St. Peter sandstone, just east of Dutchtown, Cape Girardeau County.

B. General view of the plant of the Pittsburgh Plate Glass Company, Crystal City, Jefferson County.

Analysis of St. Peter sandstone from Jackson.

SiO_2	99.52
Al_2O_3	0.16
Fe_2O_3	0.07
	99.75

Such a sand as the foregoing, if in sufficient quantity and favorably located would be of value for glass manufacture. During the course of the glass sand investigation, the writer found occasional thin beds of good sand west of Jackson, but nothing comparable to the above was noted in sufficient quantity to be of any value whatever. Personal inquiry and correspondence failed to locate the above named company, and it has been impossible to determine the locality from which the sample was secured. This area is also considered decidedly unfavorable.

The last and most favorable location in the County is just east of Dutchtown in sec. 19, T. 30 N., R. 13 E., where prominent cliffs of fairly white sandstone overlook the Mississippi lowland (Pl. XVI, A). The cover is rather heavy, but consists of loess and could be removed by hydraulic stripping. The bluffs are situated half a mile or less from the Jackson branch of the St. Louis, Iron Mountain and Southern Railroad, and topographic conditions are particularly favorable for quarrying. The following is an analysis of a sample (No. 226) taken from the cliff overlooking the road in the NW. ¼ SW. ¼ sec. 19, T. 30 N., R. 13 E.

Analysis of St. Peter sandstone from Dutchtown.

SiO_2	99.00
Al_2O_3	0.183
Fe_2O_3	0.057
CaO	0.04
MgO	tr.
Ignition loss	0.70
	99.98

The fact that the ignition loss in this sample is so high, compared with the water and CO_2 necessary to satisfy Fe_2O_3 as limonite, Al_2O_3 as Kaolinite, CaO as calcite, and MgO as dolomite, suggests the presence of considerable organic matter. The sample is from the surface of the outcrop, and if organic matter is present it would probably not show up in the deeper portion of the mass. This location is the most favorable in

the County. So far as the writer has been able to discover, however, no glass sand is now being produced or has ever been produced from this County.

BOLLINGER COUNTY.

An irregular shaped outlier of the sandstone separated by Apple Creek and its branches from the main belt, extends from the extreme northwest corner of Cape Girardeau County west of Hilderbrand into Bollinger County nearly as far west as Lixville. It occupies most of the hilltops in sec. 6, T. 33 N., R. 11 E., and sec. 1, T. 33, N., R. 10 E., and extends a short distance into adjacent sections to the west and south. Only the basal layers of the formation are present over this area in a thin veneer of highly ferruginous sandstone at most points cherty or conglomeratic, and with no possible value from an economic viewpoint. These basal beds may be in part, or even wholly, Everton. (See map, pl. XVII.)

PERRY COUNTY.

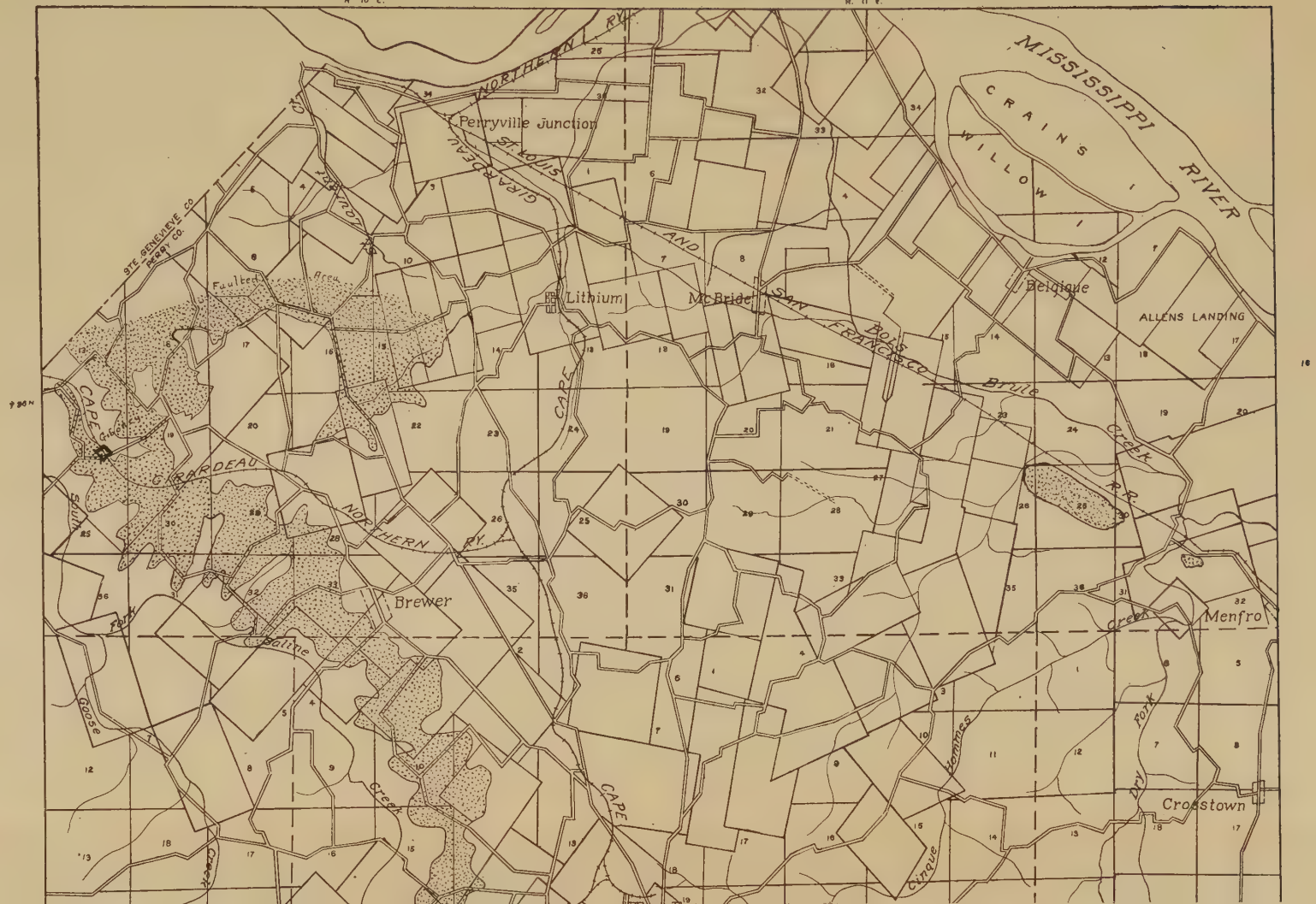
Distribution.—About 28 square miles, or not far from one-sixteenth of the County is immediately underlain by the St. Peter. The formation enters the County from the south in a belt about three miles wide, crossing the south boundary almost exactly at its central point in the vicinity of Biehle. It trends about N. 30° W., passing a mile east of Millheim, a half mile east of Highland, a half mile southwest of Perryville, a few rods west of Brewer, and crosses into Ste. Genevieve County about three miles southwest of St. Marys. South of Perryville the belt maintains a fairly constant width of from two to three miles, but north of that place it narrows down to an average of less than a mile and at places to less than half a mile.

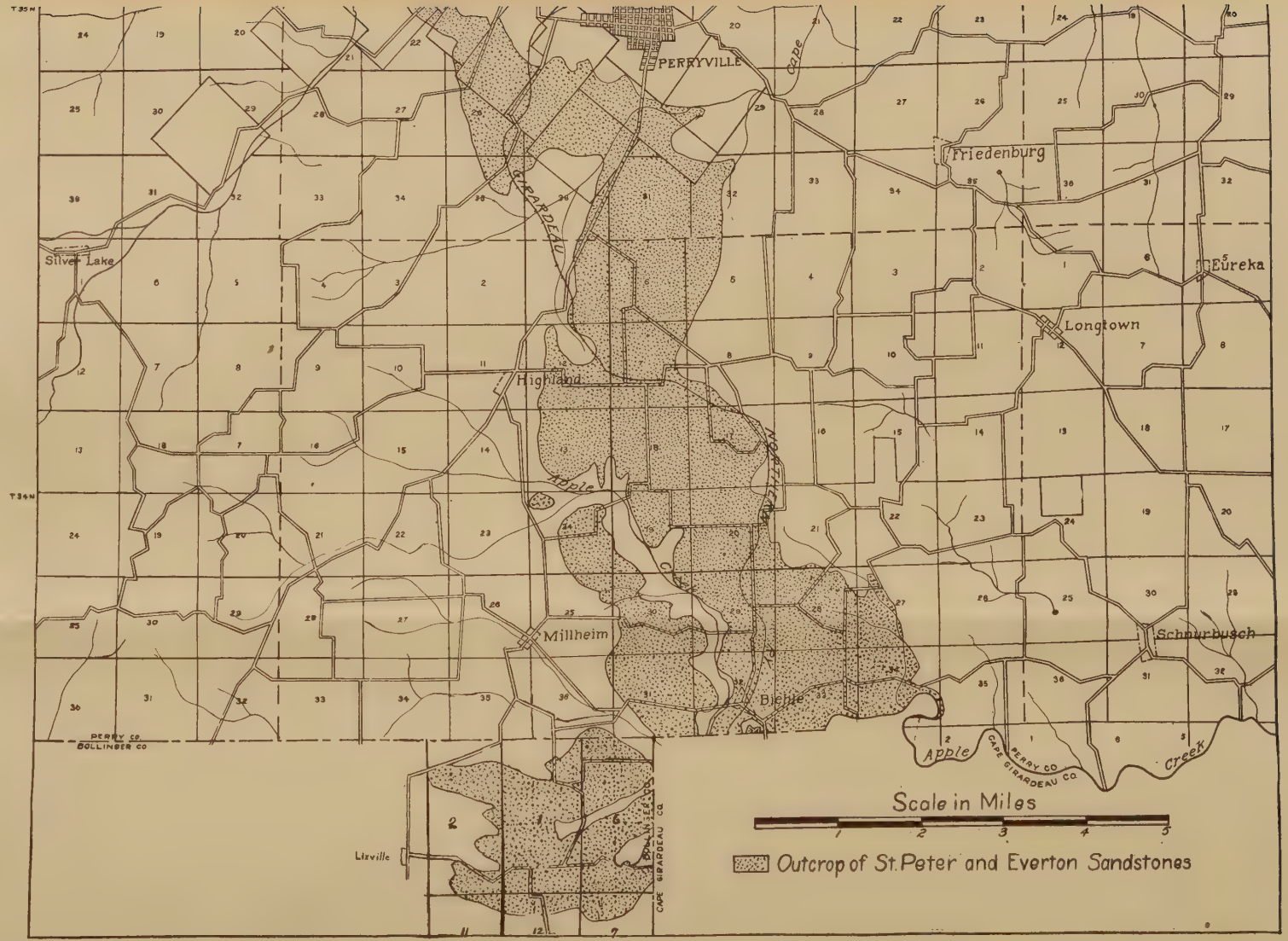
Adjacent to the zone of faulting which crosses the northern part of the County, an irregular arm of the sandstone extends from the main belt southeastward across secs. 8, 9, 10, 11, 14, 15 and 16, T. 36 N., R. 10 E., to the vicinity of Lithium. The same fault brings up inliers of the formation in secs. 30 and 31, T. 36 N., R. 12 E., and sec. 25, T. 36 N., R. 11 E. along the Mississippi bluffs. The accompanying county map (pl. XVII) shows the detailed distribution of the sandstone.

Outcrops.—South of Highland the general situation is much like that in Cape Girardeau County. With few exceptions the belt is little dissected, the outcrops are low and flat and occur

Map of parts of

PERRY AND BOLLINGER COUNTIES




PERRYVILLE
Cape
Friedenburg
GIRARDEAU
Silver Lake
Eureka
Longtown
Highland
Apple
Millheim
Bichle
Schnurbusch
PERRY CO.
BOLLINGER CO
Apple
Creek
PERRY CO.
CAPE GIRARDEAU CO.
Scale in Miles
1 2 3 4 5
Outcrop of St. Peter and Everton Sandstones
Lixville
CAPE GIRARDEAU CO.

usually at the bottoms of shallow ravines, and there are few steep bluffs and cliffs of the sandstone. Just south of Perryville, where the belt is crossed by the two branches of Cape Cinque Hommes Creek, and from Perryville northwest to the county line, where the belt lies close to the east fork of the Saline, exposures are more abundant and are frequently in the form of moderately high cliffs along the stream valleys. The inliers mentioned as occurring along the fault in the "river bluffs" stand up as bold, rugged cliffs.

General nature of the formation.—The sandstone in this County as in Cape Girardeau County is moderately fine in texture. The grains are well-rounded, and over most of the county the formation is rather friable and very ferruginous. Immediately adjacent to the zone of faulting in the northern and eastern parts of the County the sandstone in many places becomes decidedly quartzitic, and shows marked brecciation with an intricate tracery of quartz veining.

Thickness.—The only absolutely reliable figure for the thickness which the writer was able to secure in the County was from the well of the Perry County Public Utilities Company at Perryville. This well encountered the first sand at 210 feet, passed through 16 feet of alternating limestone and sandstone (the transition phase described on p.(108), entered the St. Peter proper at 226 feet, and passed into the dolomite at 308 feet. According to this record, the St. Peter has a thickness of 82 feet overlain by 16 feet of transition. A well three-fourths of a mile east of Brewer on the farm of L. S. Hogan struck the St. Peter at 77 feet and bottomed in the sand at 170 feet, a thickness of 93 feet. How much of this may have been transition similar to that described in the Perryville well, it is impossible to judge from the imperfect log reported. It is also possible that part of this thickness may represent Everton.

A fairly reliable estimate of the thickness just southwest of Brewer places it at from 125 to 150 feet, including probable Everton. Near Giboney, the St. Peter is about 75 feet thick and the Everton about the same. Shumard[1] estimated the faulted inliers along the Mississippi bluffs (secs. 30 and 31, T. 36 N., R. 12 E., and sec. 25, T. 36 N., R. 11 E.), to expose not less than 200 feet of the sandstone, but it is believed that this estimate is slightly excessive.

[1]Reports on the Geological Survey of the State of Missouri, p. 284, 1873.

Favorable localities.—White sand has been reported from several localities in this County. At the "Big Spring" near the center of sec. 25, T. 35 N., R. 10 E., about a mile southwest of Perryville, the sandstone is exposed in cliffs from 10 to 30 feet high, with only a light cover of soil. The exposure being on a steep hillside, and the location being not over half a mile from the Cape Girardeau and Northern Railroad, renders the opening of a quarry practicable. An average sample (No. 4) from the face of the cliff was analyzed and the results are given below:

Analysis of St. Peter sandstone from "Big Spring" at Perryville.

SiO_2	99.07
Al_2O_3	0.46
Fe_2O_3	0.11
CaO	0.01
MgO	0.07
Ignition loss	0.25
	99.97

This sample shows a slight buff color, but it is believed that removal of the surface would reveal a better grade of sand. This is the most favorable location noted in the County.

Along a branch of Cape Cinque Hommes Creek in sec. 5, T. 34 N., R. 11 E., and in sec. 32, T. 35 N., R. 11 E., the sandstone is exposed in steep cliffs. Where undercutting of these cliffs by the creek has caused the caving down of large masses of sandstone and the consequent production of fresh exposures, the formation shows alternating bands of slightly ferruginous and very pure white sand. It is probable that deeper within the mass the purer white phase would predominate. From 10 to 15 feet of the formation is exposed, and quarrying could probably not proceed far without encountering heavy limestone cover. The analysis of one of the white beds of the sandstone (sample No. 11) is given below. The sample was taken not far from the center of the W ½ sec. 5, T. 34 N., R. 11 E. The location is about two miles from the Cape Girardeau and Northern Railroad, with rugged country intervening. Owing to lack of transportation, to the presence of ferruginous beds in the exposure, and to the probability of heavy limestone overburden, this exposure is of very doubtful value.

Analysis of St. Peter sandstone from Perryville.

SiO_2	99.340
Al_2O_3	0.297
Fe_2O_3	0.043
CaO	0.100
MgO	0.040
Ignition loss	0.160
	99.980

Frequent reports are heard throughout the County regarding white sand in the vicinity of Lithium. One of the reported localities is in the NE ¼ of NE ¼ sec. 15, T. 36 N., R. 11 E., about a mile and a quarter straight west of Lithium. This is very close to the great fault zone which crosses the northern part of the County. The sandstone in the point of the hill at this location is white, but is decidedly quartzitic and very much brecciated and veined with quartz. Pl. XV shows the veining of the sandstone at this point. Sandstones as hard as this are sometimes crushed for glass making, but the crushing adds much to the expense of production. With as large deposits of friable sandstone as are to be found in this State, such thoroughly cemented formations are not likely to come into demand. And since the character of the formation varies greatly and irregularly near the fault, and especially so in this vicinity, it is quite improbable that the supply of even this indurated rock would prove sufficient to warrant the opening of a quarry. This bluff is located about 1¼ miles from the Cape Girardeau and Northern Railroad. The analysis of a sample (No. 133) from this location is given below. Even though the sand is sufficiently pure, for the reasons already given, the exposure has practically no chance of ever being of value for glass sand.

Analysis of St. Peter sandstone from Lithium.

SiO_2	99.72
Al_2O_3	0.02
Fe_2O_3	0.06
CaO	0.02
MgO	Tr.
Ignition loss	0.16
	99.98

Reports of white sand along the Mississippi River bluffs are also common in the County. As has already been described, a great fault brings up inliers of the St. Peter in secs. 30 and 31,

T. 36 N., R. 12 E., and sec. 25, T. 36 N., R. 11 E. Like the sandstone at Lithium, the formation at this point varies greatly and irregularly in character. Although soft and friable at places, much of it is very hard and quartzitic and intricately veined with quartz (Pl. XV). A good deal of it seems sufficiently white, but the distribution of the white and ferruginous phases at all points along the fault seems to be very irregular.

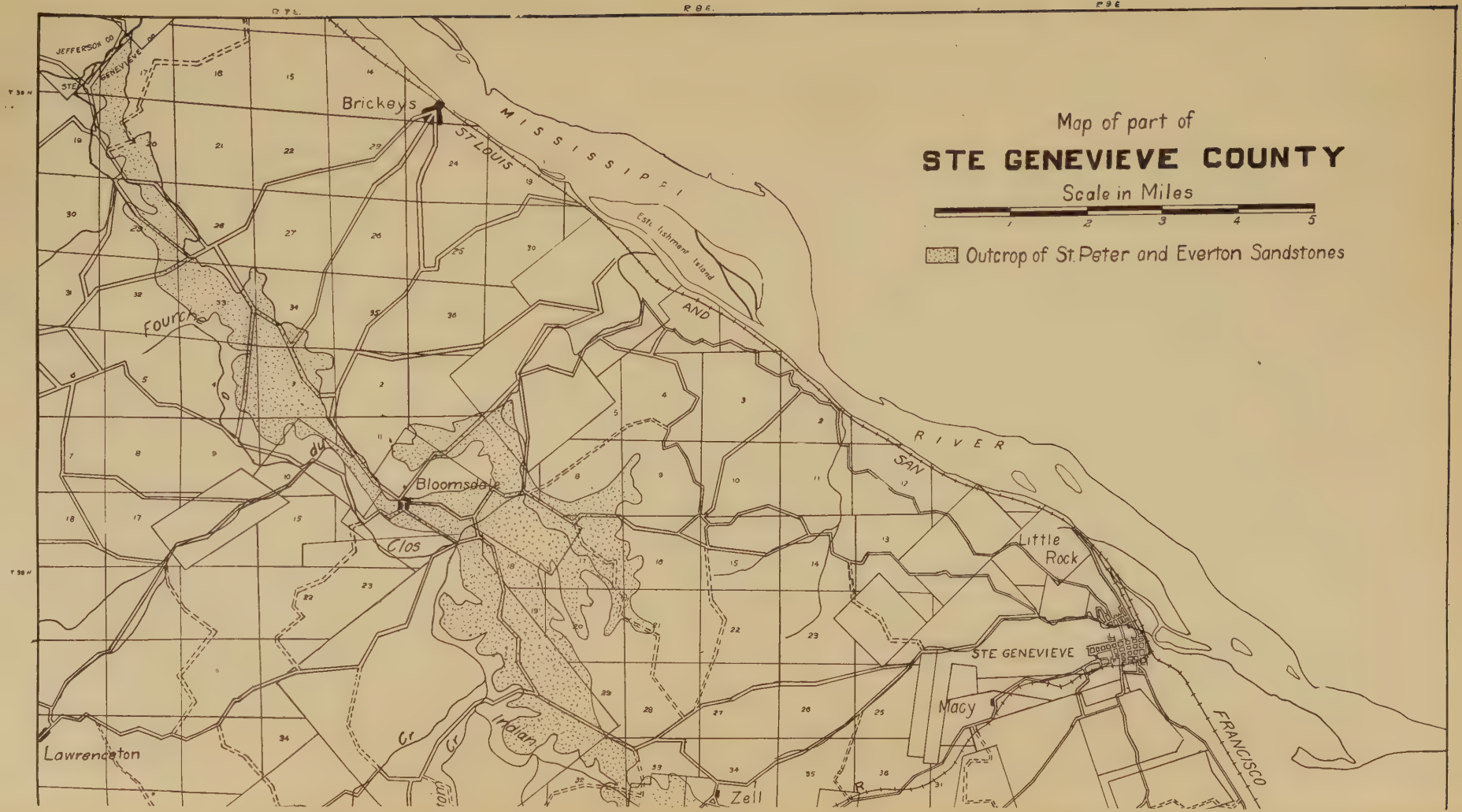
This exposure is in the form of a cliff and is immediately adjacent to the right of way of the St. Louis and San Francisco Railroad, rendering transportation facilities of the very best. Except for a moderately heavy cover, all other topographic conditions are particularly favorable to quarrying. This locality offers better chances than that west of Lithium, the chief adverse features here being the known extreme variability of the formation along the fault, and the fact that much of the formation is so hard and quartzitic.

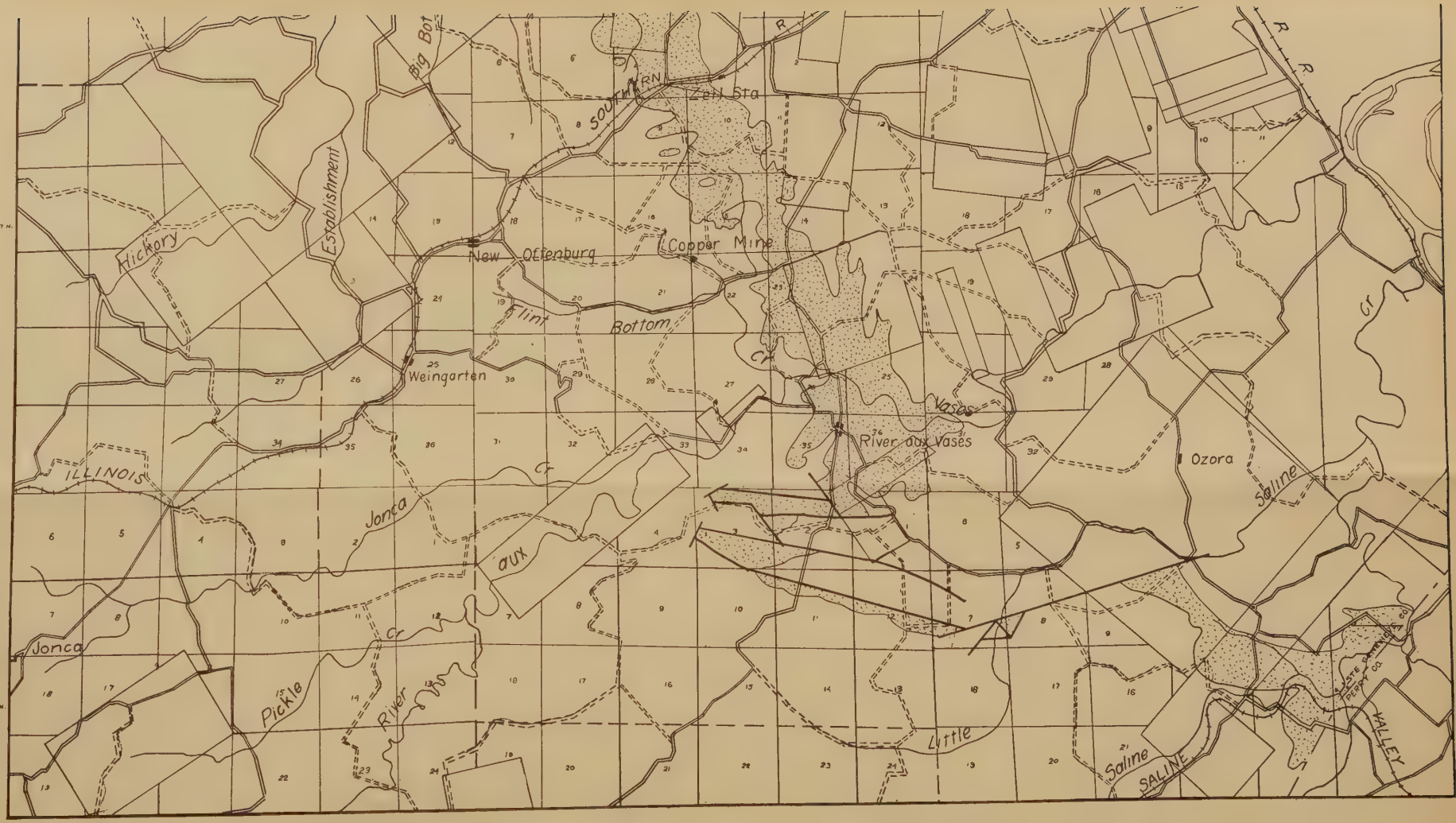
An outcrop of the Aux Vases sandstone near McBride has sometimes been mistaken for the St. Peter (see Aux Vases sandstone.)

STE. GENEVIEVE COUNTY.

Distribution.—The zone of faulting already described in the vicinity of River aux Vases, trending about N. 70° to 75° W., offsets the formation abruptly in this vicinity. South of the zone and closely adjacent to the fault plane only small irregular patches of the formation are exposed in the County. From the vicinity of River aux Vases, the belt trends N. 30° W., pa ses just west of Zell, through Bloomsdale, and enters Jefferson County across Isle du Bois Creek about two miles southwest of the Mississippi River bluffs. (See map, Pl. XVIII.)

Outcrops.—South of the fault zone, the sandstone does not outcrop freely. Just north of the fault, River aux Vases crosses the belt in a water gap in the vicinity of which considerable cliffs of the formation are exposed. From River aux Vases northwest to the vicinity of Bloomsdale the sandstone is not deeply dissected. Outcrops, though fairly numerous, are low and flat. At Bloomsdale, Establishment Creek breaks through the escarpment in a well-marked water gap, and from this creek northwest to the county boundary on Isle du Bois Creek the scarp is pronounced and steep cliff-like exposures of the formation are the rule. Over this entire distance both the St. Peter and the Everton occur in parallel belts.


R 8 E.
R 9 E
T 38 N
T 38 M
JEFFERSON CO
STE GENEVIEVE CO
Brickeys
ST LOUIS
MISSISSIPPI
Est. Ishmael Island
AND
Fourche
du
Bloomsdale
Clos
RIVER
SAN
Little Rock
STE GENEVIEVE
Macy
FRANCISCO
Irbian
Cr
Cr
Lawrenceton
Zell
Map of part of
STE GENEVIEVE COUNTY
Scale in Miles
1 2 3 4 5
Outcrop of St. Peter and Everton Sandstones


Big Bot
South Fk
Zeil Sta
R R
Establishment
Hickory
New Offenburg
Copper Mine
Flint
Bottom
Cr
Weingarten
Vases
River aux Vases
Ozora
Saline
Cr
ILLINOIS
Jonca
aux
Cr
Jonca
Pickle
River
Little
Saline
SALINE
HALLEY
T 37 N.
T 36 N.

Nature of the formation.—South of River aux Vases, along the fault zone, the formation is everywhere highly ferruginous and in many places quartzitic and greatly brecciated. From the fault zone northwestward it everywhere shows its usual characteristics. It consists of moderately fine and well-grounded grains, is very friable, and though at many points it is much iron-stained, the outcrops along very steep slopes or cliffs are usually gray to white. Fresh exposures formed by natural caving of blocks from cliff faces, from Establishment Creek northward, show the formation to be very white, where it is not stained by long exposure to weathering. The same description applies equally to the Everton sandstone.

Thickness.—Shumard[1] gives the thickness of the formation in this County as from 30 to 80 feet. A section measured by the writer in the NW. ¼ NE. ¼ sec. 29, T. 39 N., R. 7 E., showed nearly 100 feet, aneroid measurement. Not far north of the latter point St. Clair also reports 90 feet.

Presence of the Everton.—In this County the St. Peter is underlain with apparent conformity, but probably with slight unconformity, by the Everton formation, which in turn rests with unconformable contact on the Jefferson City. The Everton formation itself consists of an upper dolomite or limestone member, in many places notably sandy and averaging about 30 feet in thickness, underlain by a 60-foot sandstone member. This Everton sandstone is in most respects very similar to the St. Peter, of which it is apparently a practical continuation, as the dolomite is more or less in the nature of an extensive wedge extending into an almost uniform sandstone formation. The only characteristic feature of the Everton is the fact that at many points it is thinner bedded than the St. Peter.

Samples of the Everton show that it is fitted for glass manufacture, and in the discussion of localities the Everton, as well as the St. Peter, will be mentioned.

Favorable localities.—Near the center of the E. ½ sec. 26, T. 37 N., R. 8 E., a cliff of about 30 feet of Everton sandstone with a very thin cover of Everton limestone is exposed along the road about three-fourths of a mile north of River aux Vases. Although the weathered surface of the sandstone is moderately ferruginous, fresh blasting in a road-cut shows very white sand with only a very thin veneer of iron-stained material. The overburden is light, topographic conditions are favorable to

[1]Reports of the Geological Survey of the State of Missouri, p. 298, 1873.

quarrying, and the location is sufficiently close to River aux Vases to insure water supply for all operations. At present, however, transportation would be absolutely prohibitive, since the nearest railroad is about six miles distant and the country rough and hilly. An analysis of the sandstone (Sample No. 120) from this cliff is given below. The rock is sufficiently friable to be easily crushed.

Analysis of Everton sandstone near River aux Vases.

SiO_2	99.500
Al_2O_3	0.093
Fe_2O_3	0.067
CaO	0.120
MgO	trace
Ignition loss	0.200
	100.000

In the NW. ¼ NW. ¼, sec. 33, and the NE. ¼ NE. ¼, sec. 32, T. 38 N., R. 8 E., about 15 to 20 feet of the St. Peter is exposed. The sand is white, and apparently favorable for glass manufacture. The cover, however, is in most places thick. Water supply would have to be obtained from wells.

Across the SW. ¼ sec. 11, and the NE. ¼ sec. 10, T. 38 N., R. 7 E., is a line of cliffs exposing both the Everton and the St. Peter, the latter with fairly heavy cover of Joachim dolomite. The sandstones are moderately white even in the natural exposure and are soft and friable. Fourche a du Clos Creek just at the foot of the cliff insures ample water supply for all operating purposes. Topographic conditions, except for the heavy cover, are very favorable to quarrying operations. At present there are no transportation facilities, the cliffs lying about four miles from the railroad. The valley of Establishment Creek, however, offers an easy gateway into the country from Clement. The analysis of a sample (No. 116) taken from the face of the cliff in the NE. ¼ NE. ¼ sec. 10, T. 38 N., R. 7 E., is given below. This sample is from the St. Peter horizon.

Analysis of St. Peter sandstone from near Bloomsdale.

SiO_2	99.54
Al_2O_3	0.20
Fe_2O_3	0.10
CaO	0.02
MgO	0.02
Ignition loss	0.14
	100.02

R5E
R6E
Map of part of
JEFFERSON COUNTY
Scale in Miles
1 2 3 4 5
Outcrop of St Peter and Everton Sandstones
1 Pittsburgh Plate Glass Co.
2 Enterprise Sand and Mining Co.
3 Silica White Sand Co.
Schmitt
Sandy
Horine Sta
Herculaneum
Festus
Crystal City
Hematite
Platin
Fulcom
Danby
Harlow
MISSISSIPPI
CALICO IS
RIVER
SOUTHERN
MT
AND
ST LOUIS
SAN FRANCISCO
PLATTIN
MISS
JEFFERSON CO
STE GENEVIEVE CO

Across the SW. ¼ sec. 28, and the NE. ¼ sec. 29, T. 39 N., R. 7 E., are cliffs of good white sandstone varying from 10 to 50 feet in height, with moderately heavy limestone cover at most places. Topographic conditions are favorable to quarrying operations. The sand from this cliff was not analysed, but it is practically the same as that from the previous location. Other good cliffs also occur between this point and Isle du Bois Creek. The locations are at present without transportation facilities, being from four to six miles from the St. Louis and San Francisco Railroad. Isle du Bois Creek furnishes a natural gateway through the scarp to the region.

As far as the writer knows, no glass sand is now being produced from this County, though there is an abundance of good material in the northern part. The great drawback at present is the lack of transportation facilities along the sandstone belt.

JEFFERSON COUNTY.

Distribution.—The St. Peter sandstone enters the County from the south in a very narrow belt averaging considerably less than a mile in width. From a point on Isle du Bois Creek about two miles from Mississippi River, the belt trends about N. 40° W. to Crystal City, running throughout that distance almost parallel to the River bluffs less than two miles from the edge of the flood plain. At Crystal City a slight fold exposes the sandstone along Mississippi River. From Crystal City the belt strikes about N. 55 W., crosses Big River at Byrnesville, and passes out of the County at its extreme northwest corner. Throughout most of this distance it maintains a width of less than a mile, but suddenly widens to four or five miles on the divide between Big River and the Meramec. (See maps, Plates XIX and XXIII.)

Outcrops.—Throughout the distance from Isle du Bois Creek to Big River, the belt maintains its most characteristic escarpment feature, and over this entire stretch, cliffs of sandstone, usually with a cap of Joachim, are strikingly continuous. Between Big River and the Meramec, the escarpment is largely lost. Low flat outcrops on gentle slopes become the dominant type, although low cliffs of the sandstone are rather continuous along Bark Creek.

General nature of the formation.—Throughout Jefferson County the St. Peter is of the usual type, composed of rather

fine well-rounded grains. Although varying in hardness to the extent that the rock of the Pittsburgh Plate Glass Company needs no crushing while the use of a hammer mill is necessary at the quarry of the Enterprise Sand and Mining Company, yet at most points the sandstone is very friable, and at no point in the County does it become quartzitic as it does along the faults in Perry and Ste. Genevieve counties.

Wherever it is exposed in low flat outcrops, the sandstone shows a tendency to be moderately ferruginous. This is especially noticeable between Big River and Meramec River where cliff exposures are rare, but it is seen also at many other points throughout the belt. Between Isle du Bois Creek and Big River where the formation characteristically outcrops in cliffs, the color is usually gray to white. Any considerable iron discoloration is the exception, where the exposure is in the form of a nearly vertical or overhanging cliff.

Thickness.—A measurement made in the SW. ¼ sec. 20, T. 40 N., R. 6 E., about two and one-half miles south of Crystal City shows 80 feet of sandstone. In the NE. ¼ sec. 17, T. 40 N., R. 6 E., the formation is 75 feet thick. South of Crystal City numerous sections (exclusive of Everton) were measured, varying from 50 to 80 feet. Data from a well in Crystal City (N. ½ sec. 8, T. 40 N., R. 6 E.) seem to show a thickness of about 200 feet, but there is considerable doubt as to the interpretation of this record. The Everton is almost certainly included. At the quarry of the Silica White Sand Company, in the S. ½ sec. 36, T. 41 N., R. 5 E., the thickness is about 65 feet.

Near the center of the SE. ¼ sec. 22, T. 41 N., R. 5 E., the thickness is between 45 and 60 feet. In the S. ½ sec. 9, T. 41 N., R. 5 E., the St. Peter is only 40 feet, hand-level measurement, both contacts being well exposed. Near the center of the SW. ¼ sec. 8, T. 41 N., R. 5 E., hand-level measurements show only 35 feet of St. Peter, both contacts being well exposed. Near the NE. cor. sec. 34, T. 42 N., R. 4 E., Mr. J. S. Brown of this bureau measured 35 feet of St. Peter, both contacts again being well exposed. In all of the last four occurrences, this sandstone was underlain by thinbedded dolomite and sandstone varying from 30 to 70 feet in hickness, supposed to be the Everton. Near the center of the W. ½ sec. 7, T. 42 N., R. 4 E., only about five miles northwest of the last observation cited, a cliff shows in a single exposure 80 feet of massive white sandstone, the base of which is not exposed. This has always been

called St. Peter, but it is believed that the Everton dolomite has simply lensed out, allowing the Everton sandstone and the St. Peter sandstone to merge into one formation. Northwest from this point to Pacific the sandstone (Everton and St. Peter combined?) varies considerably in thickness from 75 feet (W. ½ sec. 7, T. 42 N., R. 4 E.) to 100 feet (Center sec. 19, T. 43 N., R. 3 E.)

Presence of the Everton.—From the vicinity of Crystal City to the south line of the County, the outcrop of the St. Peter is paralleled by that of the Everton, and the description of the one sandstone applies equally to the other. The Everton sandstone varies from 15 to 40 feet in thickness. Northwest of Festus, the detailed mapping was done by Stromme before the presence of the Everton was even suspected in Missouri. Only general information is available.

At Silica the typical St. Peter sandstone is underlain by 55 feet of sandy and pebbly dolomite, and this in turn by 17 feet of massive sandstone, slightly conglomeratic at the base. These are believed to represent the Everton. In the SW. ¼ sec. 8, T. 41 N., R. 5 E., are 50 feet of thinbedded sandstone, conglomeratic at the base and carrying dolomite lenses overlain by about 20 feet of sandy, cross-bedded dolomite. This again is thought to represent the Everton, and it is overlain by 35 feet of typical St. Peter sandstone. The farthest northwest exposure of the Everton examined is in sec. 34, T. 42 N., R. 4 E., where thirty feet of thinbedded sandstone and sandy dolomite underlie 35 feet of typical St. Peter. Beyond this point careful search failed to reveal any trace of dolomite beds within the sandstone. It is interesting in this connection to note that in the southern part of the county near Danby (sec. 7, T. 39 N., R. 7 E.) the Everton dolomite at one place only measures 5 feet in thickness, and for a distance of two or three miles north of that point seems to be lacking entirely, the two sandstones apparently coming together.

Plants in operation in Jefferson County.—There are at present in this County three companies producing high-grade silica sand from the St. Peter. They are the Pittsburgh Plate Glass Company at Crystal City, the Enterprise Sand and Mining Company between Herculaneum and Crystal City, and the Silica White Sand Company at Silica.[1]

Pittsburgh Plate Glass Company.—The central offices of this Company are in the Frick Building, Pittsburgh, Pa. The

[1]Since the above was written, the American Silica Sand and Mining Company has begun operations near Festus.

Missouri plant is located at Crystal City in Jefferson County. The quarry is just to the east of the city in the NW. ¼ NW. ¼ sec. 9, T. 40 N., R. 6 E. This is but one of several plants operated by the same Company. They have plate glass factories at Creighton, Tarentum, Ford City and Charleroi, Pa., at Kokomo, Ind., and at Crystal City, Mo. They also operate wire glass works at Floreffe, Pa., and window glass works at Mount Vernon, Ohio. The firm has sand plants at Ford City and Kenerdell, Pa., and at Crystal City, Mo. A general view of the Crystal City plant is shown in Plate XVI, B. The sand at this plant is secured from the St. Peter sandstone, and is a remarkably pure quartz sand of medium grain and thoroughly rounded and polished.

Several analyses of the sand from this quarry are available.

The following is a composite analysis furnished by the Company and represents the average of a large number of analyses of unwashed samples.

Analysis of unwashed sand from Crystal City.

SiO_2	99.405
Al_2O_3	0.210
Fe_2O_3	0.075
CaO	0.072
MgO	0.068
Ignition	0.170
	100.000

The sandstone is so slightly cemented as to crumble very readily in the fingers. In the face of the outcrop, it shows almost pure white. Thin but rather persistent bands of faint reddish to yellowish tint seem to indicate bedding. A sample (No. 33) from one of these beds was analysed, and shows only 0.14 per cent of iron oxide. This discolored sand washes practically white, and is present in such small proportions that it is not necessary to reject it.

Occasional thin seams, often not over an inch thick, show a faint greenish tint. Such a seam, about four inches thick and known to the quarrymen as a "mud seam" forms the present roof through much of the quarry and is remarkably persistent. It occurs about 15 to 20 feet below the top of the sandstone. An analysis of a sample (No. 32) taken from the mud seam shows 0.243 per cent iron oxide and 1.037 per cent alumina.

The St. Peter sandstone here outcrops in a irregularly dissected north-south escarpment which constitutes the western

A. Quarry and sand plant of Pittsburgh Plate Glass Company, Crystal City, Jefferson County. Shows cliff of St. Peter sandstone capped with Joachim dolomite.

B. Quarry of Pacific Glass Sand Company, near Pacific, in St. Louis County. St. Peter sandstone capped with Joachim dolomite.

face of a pronounced ridge which forms the divide between Plattin Creek and the Mississippi (Pl. XIII, B). The general dip of the rocks in this vicinity is from ½° to 20° to the northeast, conforming to its location on the northeast flank of the Ozark dome.

The fact that the sandstone in this region forms an escarpment facing the Plattin Creek lowland causes the formation to outcrop over a very narrow belt, varying from a hundred yards to perhaps half a mile. This is interrupted at the north by the Plattin Creek water gap, and extends indefinitely southeastward. For much of the distance along this escarpment in the vicinity of Crystal City, the outcrops are in the form of prominent cliffs of sandstone rising from 15 to 50 feet above the creek level and capped with Joachim limestone (Pl. XX, A). The Company's quarry is located on a sharp reentrant in this cliff, with between 40 and 50 feet of sandstone exposed from the creek level to the Joachim cover.

The river front of the Mississippi and the inner lowland west of the ridge here unite, thus forming the obvious pathways for railroad building and placing the quarry site within easy reach of the St. Louis and San Francisco Railroad and the Mississippi River and Bonne Terre Railway.

The overburden consists entirely of Joachim and younger limestones and thickens very rapidly into the bluff from a few feet to over a hundred feet. Before quarrying had proceeded far, it became impossible to handle so much cover; consequently all operations are now carried on by underground methods (Pl. X, B).

The sandstone extends considerably below the level of Plattin Creek, which controls the water level in the mine. The large porosity of the sandstone gives a free circulation, and water is so abundant that at present the floor of the mine is controlled by the position of the water table. High water in the Mississippi sometimes enters the workings and stops all operations. Plattin Creek and shallow wells give sufficient water at all times for operating purposes.

At the escarpment face at the west entrance to the mine, the height from the level of the ground water which forms the present floor of the mine to the "mud seam" which forms the roof is about 25 feet. Farther under the hill at the present eastern limit of the workings, the height of the roof, owing to the easterly dip, is only 12 feet above the water level. Since

6 feet is about as low a face as it is economically possible to work, the eastern extent of the workings is limited. There are, however, several possibilities by which the available supply can be augmented. If the water could be got rid of, at least 30 feet of very pure and extremely friable sand might be available below the present floor of the mine. This would necessitate pumping operations and the cost would probably be prohibitive.

About 25 per cent of the present area of the mine is occupied by pillars left to support the roof (see mine map, Pl. XXII). The possibility of removing these and letting the roof cave has been considered, but it is thought this would involve too much expense and too much danger to be a feasible undertaking.

Recent plans, already beginning to be put into operation, are to work out the sand above the "mud seam" to within about two or three feet of the top of the formation. This sand, though less pure than that beneath, can be used. It is considerably harder and more expensive to crush. It is believed by the management that this is the most feasible way to increase the available supply, and will give about as much more sand as has already been mined out.

The Company has recently purchased more land along the face of the cliff south of the present quarry, with the idea of opening up another quarry as the present one becomes exhausted. There is almost unlimited supply of sandstone to be had along this escarpment for two or three miles south of Crystal City, but most of it would have to be quarried by underground methods on account of the heavy overburden of limestone.

It has been suggested that as the sandstone is so extremely friable the material below the water level might be secured by blasting to break up the rock, and by pumping directly from the mine floor with large pumps as is done at Ottawa, Ill.[1]

The present quarrying operations cover an area of about 1200 feet north and south by 1400 feet east and west. The entire working is underground, the overburden being so heavy that stripping and open pit work are practically out of the question. Drilling is by means of compressed air. The sand is blasted down in the mine, loaded by hand into mine cars, and hauled electrically to a point near the main entrance, where it is dumped into a coarse rotary cylindrical screen. It is washed through this screen with water, and is so friable that in the

[1]Burchard, E. F., Mineral Resources of the United States for 1911, pt. 2, p. 598.

A. Plant of Enterprise Sand and Mining Company, Herculaneum, Jefferson County.

B. Quarry of Silica White Sand Company, Silica, Jefferson County. St. Peter sandstone.

process it becomes very completely crushed, the few remaining lumps being removed by the screen.

From the tank underneath the screen a centrifugal pump forces the sand into steeply inclined troughs over riffles into a settling tank. The fine water-floated waste which is used in the grinding sand carries off an appreciable yellow discoloration. The grinding sand is pumped directly from the quarry to the factory and is not dried.

The coarser sand, known as "melting sand," is transferred on a belt conveyor to a rotary Cummer dryer, and after being completely dried is passed through a 14-mesh screen to remove any remaining lumps. It is then elevated to hoppers, loaded into cars by gravity, and hauled to the factory.

This Company produces sand only for its own glass factories. Most of the output of this quarry is used by the Crystal City factory, though occasional shipments are made to other plants of the Company. Of a daily output of about 400 tons, approximately 100 tons are used for melting and 300 tons for grinding.

Enterprise Sand and Mining Company.—This quarry is located about a mile north of Festus and two miles south of Herculaneum in Jefferson County, near the center of the SW. ¼, sec. 31, T. 41 N., R. 6 E. The office is at Herculaneum. Plate XXI, A shows a view of the plant.

Here as elsewhere the St. Peter consists of very pure quartz sand with well-rounded and polished grains. The Company reports an analysis of unwashed average quarry-run sand which shows 99 1/8 per cent silica. The rock is considerably harder at this quarry than at the quarry of the Pittsburgh Plate Glass Company, and requires special crushing. In the natural outcrop, the sandstone shows much more highly ferruginous surfaces here than in the neighborhood of any other quarry visited. Natural cliffs of good white sandstone are nowhere exposed in the immediate vicinity. In fact, the opening up of this quarry in a locality where all the natural outcrops are much discolored with iron is one of the most favorable indications that the ferruginous phase of the St. Peter in the southern counties is probably only superficial, and that good white sand may be secured in those localities by removing the veneer of iron stained sand on the surface. Although the natural outcrops at this quarry are ferruginous, the sandstone along the freshly opened face is very white and of a high degree of purity, as is shown by

the analysis cited above. It is interesting to note that in a very short time the quarry face, where not kept freshly open by active operation, becomes stained a deep red by the wash from the ferruginous overburden.

The quarry is located in a low saddle in the divide between Plattin and Joachim Creeks, where the overlying Joachim limestone has been completely cut away by the opposing headward erosion of two small branches working back into the divide. This gives a long narrow north-south belt of the St. Peter from one-eighth to one-half mile wide, outcropping in the two branches with ridges capped on either side by Joachim. The natural sandstone slopes here, though steep, are not precipitous. The quarry is on the west side of the depression. At present no limestone overburden is being handled, though as the quarry is pushed westward into the hill, the limestone will ultimately be reached. The quarry carries a cover of from 1 to 10 feet of loess with a little residuum at the base of the loess. The present stripping averages about 4 feet. The quarry is free from water as the floor is above the water table, and the porous sandstone allows surface run-off to sink away rapidly. Water for operating purposes is secured from a well.

The work is all open pit, the working face being about 300 feet long and 40 feet high. Stripping is done by team and scraper, the refuse being dumped over the side of the bluff. Drilling is by means of compressed air, the face is blasted down, and the blocks of sandstone loaded by steam shovel into quarry cars. Haulage is by horse power to the foot of the incline, and then by drum and cable into the plant. From the quarry cars the blocks are dumped into the hopper of a Williams Hammer Mill, where the sandstone is crushed to sand. The sand is neither washed nor dried, but is passed through ¼-inch to ½-inch mesh screens before going to the cars. There are storage bins with a capacity of about three cars. The daily capacity of the plant is about 1000 tons.

The chief uses of this product are for core and moulding sand and for flux. A little is used for glass making. A spur of the Mississippi River and Bonne Terre Railway runs to the quarry.

Silica White Sand Company.—This quarry is located at Silica about one and one-half miles northwest of Festus, Jefferson County, near the center of the S. ½ sec. 36, T. 41 N., R. 5 E. The office address is Festus.

The St. Peter here is very similar to that at the Pittsburgh Plate Glass Company's quarry. As usual it consists of very pure quartz grains, moderately fine, well-rounded and polished. The rock here is more friable than at the quarry of the Enterprise Sand and Mining Company, breaking down rather easily into its constituent grains. Natural outcrops in the vicinity, for the most part in steep or overhanging cliffs, show gray to white surfaces. The quarry face is very white, but shows occasional reddish and greenish bands similar to those described in the quarry of the Pittsburgh Plate Glass Company.

This quarry is located at the western extremity of a long narrow salient of the St. Peter-Joachim escarpment which extends in an east-west line between the water gaps of Joachim Creek and Plattin Creek through the St. Peter-Joachim ridge (Pl. XIII, B). In several places along this ridge, the Joachim has been entirely removed, but at the western end where the quarry is located, there is still considerable dolomite cover. The ridge is steep and narrow with fairly continuous cliffs on the south side for a distance of about a mile and a half, and with steep slopes and occasional cliffs on the north side. The sandstone belt averages 100 to 300 yards in width on the south and west sides of the ridge where the slopes are steep, and from ¼ to ¾ of a mile on the north where the slopes are more gentle. The western end of the ridge is naturally precipitous, and ending as it does abruptly in high cliffs at the right of way of the St. Louis and San Francisco Railroad, forms a very favorable location for a quarry. An overburden of from one to eight feet of Joachim dolomite caps the St. Peter near the center of the quarry. In other parts the cover is thinner, and over part of the area consists only of 3 to 10 feet of soil.

Most of the work at this plant is open pit (Pl. X, A), but small tunnels are also being operated (Pl. XXI, B). The present working face is about 2000 feet long and from 50 to 65 feet high. Practically the entire thickness of the sandstone is utilized. In the northwest part of the quarry the Everton limestone is but a few feet below the present floor. The material is drilled and blasted down, loaded by hand to quarry cars, and hauled by horses or mules to the crusher which is a rotary drum with one-inch holes. The sand, which is neither washed nor dried, is loaded by gravity to the cars.

The chief uses of the product are for core sand, moulding sand, and glass manufacture. Small amounts have been sold

for concrete, plastering, and brick work, but it is not coarse enough to be a satisfactory structural material.

Favorable localities.—In Doolin Hollow in the SE. ¼ SE. ¼ sec. 27, T. 40 N., R. 6 E., there is exposed a cliff of about 25 feet of unusually friable white sandstone. Limestone cover is moderately heavy, but other topographic conditions are favorable to quarry operations. The cliff is about 1½ miles from the St. Louis and San Francisco Railroad, to which Doolin Hollow offers a natural gateway.

The following is the analysis of a sample (No. 109) from this ledge.

Analysis of St. Peter sandstone from Doolin Hollow.

SiO_2	97.60
Al_2O_3	0.20
Fe_2O_3	0.10
CaO	1.02
MgO	0.22
Ignition loss	0.72
	99.86

The high lime content is due to the fact that the sample was taken near the Joachim contact.

In the extreme NE. ¼ NE. ¼ sec. 33, T. 40., R. 6 E., are exposed 30 to 40 foot cliffs of moderately white sand with little or no cover of any sort. The upper few feet of the sandstone, however, are badly iron-stained. The topographic conditions are very favorable to quarrying, but transportation conditions are not promising. The only way to reach the point from the St. Louis and San Francisco Railroad would be up Selma Hollow, a distance of between three and four miles. No analyses were made from this ledge.

Through the E. ½ secs. 17 and 20, T. 40 N., R. 6 E. are almost continuous cliffs of sandstone, varying from 20 to 70 feet in height and usually capped with heavy limestone cover. Most of this exposure is very white, and appears to be fully the equal of the sandstone exposed in the cliffs at Crystal City. This line of cliffs exposes both the Everton and the St. Peter. Topographic conditions are favorable to quarrying. The line of cliffs is located from half a mile to a mile east of the Mississippi River and Bonne Terre Railway.

Beginning in the NE. ¼ NW. ¼ sec. 6, T. 40 N., R. 6 E. and extending almost continuously across the S. ½ SW. ¼ sec. 31, T. 41 N., R. 6 E., and across the S. ½ SE. ¼ sec. 36, T. 41 N.,

R. 5 E., to the quarry of the Silica White Sand Company, runs a line of prominent sandstone cliffs. Toward the west end of this exposure considerable quarrying has been done, both by open pit and tunnel methods. The quarries are now abandoned. The writer was unable to learn definitely why it was necessary to suspend operation, though it was reported that lack of a railroad spur and consequent cost of haulage was the chief trouble. All along this line of cliffs the sandstone is very white and moderately friable. The cover varies greatly from almost nothing to heavy beds of limestone. The cliffs are located from ½ to ¾ of a mile north of the St. Louis and San Francisco Railroad. Topographic conditions are favorable to quarrying, but the building of a railroad spur would be expensive. Aerial trams might be used to good advantage.* No analyses were made from this locality, but the sand appears to be the equal of that in the quarries at Crystal City and Silica.

Low cliffs of moderately white sandstone with light overburden are located in the SW. ¼ SW. ¼ sec. 22, and the SE. ¼ sec. 21, T. 41 N., R. 5 E., at a distance of two miles west of the St. Louis, Iron Mountain and Southern Railway. The intervening country is moderately rugged. The sand is very friable, and topographic conditions are favorable to the easy opening of a quarry, but transportation facilities are wanting. No analyses were made from this cliff.

In the NW. ¼ sec. 18, T. 42 N., R. 4 E., from 25 to 40 feet of moderately white sandstone are exposed in cliffs along the road. Limestone cover is heavy. The point is about eight miles from the St. Louis and San Francisco Railroad, and the only gateway is along the valley of the Big River. An analysis of sample No. 57 from this cliff is given herewith.

Analysis of St. Peter sandstone from near Byrnesville.

SiO_2	99.32
Al_2O_3	0.12
Fe_2O_3	0.07
CaO	0.15
MgO	0.09
Ignition loss	0.29
	100.04

Just north of the above location near the center of the W. ½ sec. 7, T. 42 N., R. 4 E., a very prominent cliff exposes 50 to

*Since the above report was written, a quarry has been opened in this cliff, and the sand is delivered to the railroad by aerial tram.

70 feet of good white sandstone. Limestone cover, thin at the cliff edge, thickens rather rapidly into the hill. The topographic conditions are favorable to quarrying operations, but the same thing may be said with respect to transportation that was said regarding the cliff mentioned in the preceding paragraph. No sample was analysed from this exposure.

In the SW. ¼ SW. ¼ sec. 34, T. 43 N., R. 3 E., a 20-foot cliff of sandstone is exposed on the west side of the road. Recent caving of a large block shows a fresh face. Many bands show a faint ferruginous stain, alternating with bands of pure white sandstone. There are also many mud seams, similar to the one described from the quarry at Crystal City. The aggregate of these greenish seams makes up between one-fourth and one-half of the cliff face. The ledge is located about five miles from a railroad. Topographic conditions, including very light soil cover, are favorable to quarrying. But the presence of the argillaceous "mud seams" renders the sand of little value except for low grades of glass.

Hon. H. H. Weaver reports that about 35 or 40 years ago sand was quarried on his place (NW. ¼ of S. W. ¼ sec. 36, T. 40 N., R. 6 E.) and hauled by team to Rush Tower, where it was loaded onto barges and shipped to St. Louis. This was before there was any railroad in the vicinity. The sand is said to have been used in glass manufacture. The sand exposed at the old quarry is badly discolored on the surface and no evidence is available regarding the purity of the sand shipped from this locality.

ST. LOUIS COUNTY.

Distribution.—Less than two square miles in this County are immediately underlain by the St. Peter sandstone. This area lies in the extreme southwestern corner, where the Meramec breaks through the escarpment (see map, Pl. XXIII).

Outcrops.—At this point the escarpment trends east and west, facing south. From the western boundary of the County, a line of cliffs, somewhat irregularly dissected, extends for about a mile eastward, and exposes the St. Peter, for the most part with a heavy cover of Joachim. Owing to the easterly dips, the height of the sandstone exposures decreases to the east, and the Joachim cover thickens proportionately.

Nature of the formation.—The sandstone here consists of the usual moderately fine, well-rounded and polished grains of pure

quartz. Though for the most part rather friable, there are even in this small area considerable differences in the degree of cementation, the rock at the east end of the line of cliffs being more indurated than that at the west. At a few places, broad flat exposures show ferruginous surfaces, but for the most part the sandstone here is either gray or white in the natural outcrop along the cliffs.

Thickness.—No exact measurements of thickness are available in the outcrops, but the amount exposed in one of the quarries, combined with a well section reported from the same point, gives between 80 and 100 feet as the probable thickness in this locality.

Plants operating in the County.—At the present time there are only two plants operating in St. Louis County, the Pacific Glass Sand Company and the Tavern Rock Sand Company.

Pacific Glass Sand Company.—The quarry is located about a half mile east of Pacific in the SW. ¼ NW. ¼ sec. 7, T. 43 N., R. 3 E. It is only a few rods east of the line between Franklin and St. Louis counties. The office is at Valley Park.

The St. Peter here consists of the usual moderately fine-grained, pure, quartz sandstone, the individual grains being well-rounded and polished. The sandstone, though moderately friable, requires crushing. The natural outcrops adjacent to the quarry are gray to white.

The following analyses of the sand from this quarry are available. On p. 124, analysis number "I" has previously been published, and analysis "C" was furnished the writer by the Company.

The quarry is located on the southwest side of a long narrow salient of the St. Peter-Joachim escarpment. The general trend of the escarpment is nearly east and west, and this spur extends southeast and northwest. Along this ridge, the sandstone outcrops for the most part in cliffs or very steep slopes in a belt not over 50 yards wide (Pl. XX, B.)

The sandstone outcrops down to the level of the alluvium of the Meramec River plain, and the entire ridge is capped with Joachim and younger rocks. The overburden consists of Joachim limestone, averaging perhaps 3 feet thick at the quarry face but thickening rapidly into the hill. The floor of the quarry is far enough above the valley bottom to be self-draining. Water for operating purposes is pumped from Meramec River.

The work is both underground and open pit, about half the

sand coming from the tunnels (Pl. XXV, A) and half from the pits (Pl. XXIV, A). The working face extends between 800 and 1000 feet, and varies from 50 to 90 feet in height (Pl. XX, B). The depth of the sandstone below the floor is not known. The main tunnel has been driven back into the hill about 400 feet and has several branches. The capacity of the plant is 300 tons in 10 hours.

Drilling is done by compressed air, the material is loaded by hand into quarry cars, and hauled by drum and cable up the incline into the plant (Pl. XXIV, B). The sandstone is crushed in a Williams Hamner Mill and screened through a 48-inch cylindrical rotary screen with about ¼-inch mesh. The coarse screenings are carried by a conveyor back into the crusher. The sand then runs successively into a series of five washing tanks, each of which has a jet of water under considerable prss-sure. The coarse sand settles to the bottom in each and is pumped into the next tank, while the finer material is water-floated into a larger tank on the side. From the last of the series of five tanks, the coarser sand is carried by an auger conveyor on to a belt conveyor and thence into large drainage tanks, where the sand is allowed to stand a day to get rid of as much water as will run off. It is then drawn into drying bins through which coils of steam pipes run. Here it is thoroughly dried. It is then elevated by bucket elevator to the spouts, which carry it to the cars. At these spouts are inclined screens, 20-mesh to the inch, through which the dried sand is run before going to the cars. The coarse material from these screens is waste, and the material going to the cars is the "melting sand" used in making the glass.

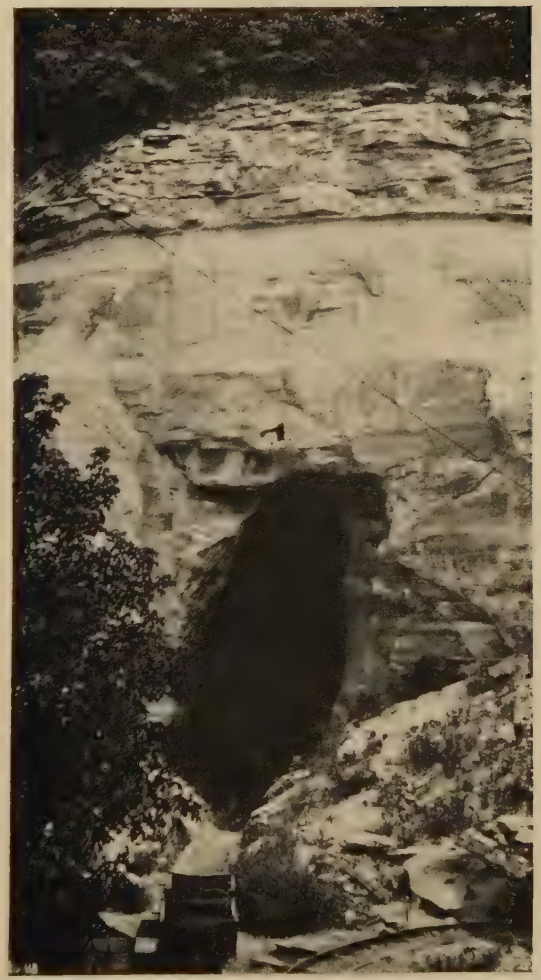
In the washing process, it was noted that the fine water-floated material was washed into a large tank. This material, which carries off an appreciable discoloration, is pumped from this tank into large drainage bins, where it is allowed to drain but is not further dried. This goes into the "grinding sand" used in grinding the glass.

The proportions of grinding sand and melting sand vary. Near the bottom of the quarry about two-thirds of the material is the coarser melting sand and only one-third the grinding sand. Near the upper part the proportions are said to be nearly reversed, the fine grinding sand making the larger part of the output. By proper choosing, the proportions can be regulated as desired.

The output of this quarry at the time of the writer's visit

A. Quarry of Pacific Glass Sand Company, Pacific, in St. Louis County. Open pit work in St. Peter sandstone.

B. Plant of Pacific Glass Sand Company, Pacific, in St. Louis County.



A. Tunnel of Pacific Glass Sand Company, near Pacific, in St. Louis County. Shows St. Peter-Joachim contact.

B. St. Peter sandstone quarry of Tavern Rock Sand Company, Klondike, St. Charles County. Aerial tram to remove stripping.

was all used at the Company's glass plant at Valley Park. In the past considerable unwashed foundry sand has been shipped to St. Louis as moulding sand for steel casting and as core sand. Both the Missouri Pacific Railway and the St. Louis and San Francisco Railroad furnish transportation facilities.

Tavern Rock Sand Company.—This Company operates three quarries, one at Klondike in St. Charles County (Pl. XXV, B), one in Pacific in Franklin County (Pl. XXVIII, B), and a third about 1¼ miles east of Pacific in St. Louis County (Pl. XXVI). The St. Louis County quarry of this Company is near the center of the SW. ¼ sec. 8, T. 43 N., R. 3 E., on the bank of Meramec River.

The sandstone consists of very pure, well-rounded grains of quartz of medium size. There is given below an analysis of what is said to be the average unwashed sand from the quarry:

Analysis of sand from Tavern Rock Company.[1]

Absolute silica	99.97%
Iron, alumina, and lime	0.03%
	100.00%

The sandstone is moderately well bedded, the bedding planes being emphasized by a slight ferruginous stain and by the pale-green tint of the so-called mud seams. For the most part, the color in the quarry face is white, but near the top of the quarry the sand is distinctly ferruginous. Natural outcrops in the immediate vicinity are also somewhat iron-stained. One thin bed yields a rather sharper and coarser sand than the average, which is used for sawing stone.

This quarry is located on a southward projecting salient of the St. Peter-Joachim escarpment. As the general dip of the rocks is northeastward and as this quarry is nearly two miles east of those in Pacific, it follows that the altitude of the St. Peter-Joachim contact is considerably lower here. The quarry is located at the extreme south end of a low sandstone ridge almost at the level of Meramec River. The Joachim is completely removed on this part of the hill. The overburden consists entirely of loess, varying from 1 to 10 feet and averaging about 6 feet. The water table controls the position of the floor of the quarry, and as the sandstone is very porous no drainage is necessary. The Meramec River furnishes water for operating purposes.

[1]Analysis (By Regis Chauvenet & Bros., St. Louis, Mo.) furnished by the Tavern Rock Sand Company.

There is somewhat over 500 feet of working face at the present time, varying in height from 10 to 50 feet. All the work is open pit (Pl. XXVI, A). The capacity of the plant is 450 tons in 10 hours. The overburden of soil is broken up by blasting, and the loosened material is removed as in hydraulic mining, being washed into a flume with a jet of water and carried down into the river (Pl. XXVI, B). The flume is carried across the pit on trestle work. Drilling is done by steam, the rock is blasted down, loaded into quarry cars, hauled to the plant by drum and cable, and dumped into the crusher, an Allis-Chalmers gyratory. The sand is screened through a 10-mesh screen and dried in a rotary crude-oil dryer. No sand is washed in this quarry. Most of the output is used for glass sand, but a small amount of stone sawer's sand is also produced.

Favorable localities.—Most of the available quarry area along the outcrop of the sandstone in this County is already occupied. Just east of the quarry of the Pacific Glass Sand Company, near the center of the N. ½ sec. 7, T. 43 N., R. 3 E., a deep ravine forms a sharp re-entrant angle in the escarpment. The west slope of this ravine (which is the east slope of the hill into which the Pacific Glass Sand Company is now quarrying), shows immediately adjacent to the right of way of the Missouri Pacific Railway, a good white sandstone with heavy limestone cover in cliff exposures. The east slope of this same ravine shows an abandoned quarry (Pl. XIII, A) with a working face about 400 feet long and from 30 to 60 feet high. Work has been carried on until the overburden of limestone became too heavy to strip, after which several small tunnels were started. The sand here is reported to be of excellent grade and is very white and friable. Heavy overburden was said to be responsible for abandoning the quarry.

FRANKLIN COUNTY.

Distribution.—Only about six square miles in Franklin County are immediately underlain by the St. Peter. All of this area is in the northeast corner of the County, and with the exception of two or three small patches of no consequence, it lies in an irregular belt northwest of Pacific on the divide between the Meramec and the Missouri (See map, Pl. XXIII.)

Outcrops.—At Pacific, where the Meramec crosses the belt and at Becker where the Missouri cuts through the formation, outcrops occur largely in the form of very steep slopes or cliffs,

A. Tavern Rock Sand Company's quarry in St. Peter sandstone, near Pacific, in St. Louis County. The overburden is loess.

B. Tavern Rock Sand Company's quarry near Pacific, in St. Louis County. Loess overburden stripped hydraulically.

and are rather continuous. Near the center of the divide, where dissection is not so deep, a much larger proportion of the outcrops are low and flat, occur in the valley bottoms, and are more isolated.

Nature of the formation.—The formation consists of a moderately fine-grained sandstone, the individual grains being well-rounded and polished. Although it is a very friable rock, there is considerable difference in its hardness. At the Glaser quarry in Pacific the sand is so soft as to crumble completely during handling, while at the quarry of the Grays Summit White Sand Company a jaw crusher is necessary. For the most part the sand is very white, showing gray to white on the natural outcrop, especially along the Meramec and Missouri valleys where the outcrops are in the form of cliffs.

Along the middle of the divide and in general wherever the outcrop is low and flat and partially covered with soil, the formation shows much iron stain from the leaching down of ferruginous material.

Thickness.—A total thickness of 167 feet, determined in part from the quarry exposure and in part from a drill hole, has been reported at Grays Summit,[1] but this thickness seems excessive. About three miles northwest of Grays Summit, a measurement somewhat indefinite, owing to inability to locate exactly the contacts of the sandstone, shows over 80 feet and less than 140 feet of the St. Peter. At Becker on Missouri River, over 75 feet of the formation is exposed in a cliff, and just across the river at Klondike in St. Charles County the formation has a thickness of 105 feet. It is entirely probable that the lower portion of this section includes sandstones equivalent to the basal Everton sandstone farther southeast.

Plants operating in Franklin County.—There are three plants in this county either actively operating or prepared to operate. They are the Grays Summit White Sand Company at Grays Summit, J. W. Glaser in Pacific, and the Tavern Rock Sand Company, which operates a small quarry in Pacific in addition to its quarries in St. Louis and St. Charles counties.

Grays Summit White Sand Company.—This quarry is located one-half mile northeast of Grays Summit in the SW. ¼ SW. ¼ sec. 4, T. 43 N., R. 2 E. The office address is St. Louis.

The formation is a very pure quartz sand. The following is the analysis of an average sample quarry-run sand, unwashed:

[1]Burchard, E. F., Mineral Resources of the United States for 1911, pt. II, p. 600.

Analysis of sand from Grays Summit White Sand Co.[1]

Dried at 212° F.	
Silica	99.68
Iron	Trace
Alumina	0.18
Loss on ignition	0.14
	100.00

In this vicinity most of the natural exposures are rather ferruginous. The sandstone in the quarry face is white, except for a few faintly discolored bands and a rather ferruginous crust at those places where the only overburden is the ferruginous soil. The sandstone is not so friable as in the Glaser quarry at Pacific.

In this locality the St. Peter-Joachim escarpment trends nearly east and west, facing south toward Brush Creek. The slopes are more gentle, the escarpment is not so sharply dissected, and the sandstone belt is straighter and considerably wider than at Pacific. The escarpment occasionally has low cliffs, but for the most part consists of slopes rather than cliffs. This is due largely to its position well up on the divide between the Meramec and the Missouri. The overburden in places consist of loess only, at other points of both limestone and loess and varies from one to 20 feet in thickness, averaging about 10 feet.

Although the quarry floor slopes in all directions to a deep level at the center (Pl. XXVIII, A), it has not been necessary to take any special precautions for drainage. The porosity of the formation has carried the surface drainage off through the sandstone of the floor, which lies above the water table. Water for operations is secured from a deep well.

Work is all open pit. The present working face is 300 or 400 feet in length and varies from 20 to 75 feet in height. The thickness of the sand below the present floor of the quarry is not definitely known. Stripping, where the cover is of soil, is carried on by means of a common scraper, operated by drum and pulling-and-backing cable. Steam drills are employed. The material is blasted down from the face, loaded into the quarry cars by hand, and hauled to the plant (Pl. XXVII, A) by drum and cable. The rock is crushed in a jaw crusher, dried in a

[1]Analysis (by Robert W. Hunt and Co., Engineers, St. Louis office) furnished by Grays Summit White Sand Company.

A. Plant of Grays Summit White Sand Company, Grays Summit, Franklin County.

B. Plant of Tavern Rock Sand Company, Klondike, St. Charles County. Shows plant below quarry, allowing gravity operation.

A. St. Peter sandstone quarry of Grays Summit White Sand Company, Grays Summit, Franklin County.

B. Quarry of Tavern Rock Sand Company, in Pacific, Franklin County. St. Peter sandstone.

rotary oil-burning dryer, passed through a 14-mesh screen, and elevated to the bins, from which chutes carry it to the cars.

The chief uses of the sand are for steel foundries, marble cutting and grinding, manufacture of glass, and for the white finish on terra cotta. A spur of the Missouri Pacific Railway runs to the plant. During the past few years, shipments have been made over a large radius, points in Missouri, Illinois, Indiana, Kansas, and Texas, supplying markets for the output. This quarry and plant were idle during 1914 when visited by the writer.

Tavern Rock Sand Company.—This Company with offices in St. Louis operates three quarries, one at Klondike in St. Charles County, one about one and one-fourth miles east of Pacific in St. Louis County, and a third located within the limits of Pacific, in Franklin County. The quarry located in Pacific is near the center of the N. ½ sec. 12, T. 43 N., R. 2 E., only a few blocks northwest of the Union Station, and constitutes one of the most prominent landmarks of the vicinity (Pl. XXVIII, B.)

The sand is the usual medium-grained, well-rounded and polished St. Peter. At this point, it is very much more friable than in quarries either to the east or west. The ordinary process of caving down the sand and handling it breaks it up to the extent that no regular crushing is necessary. All of the sand of this quarry is very white. The color bands of reddish and greenish tints seen at so many places are less prominent here than elsewhere, though they are not entirely absent.

The outcrop consists of cliffs or very steep slopes of St. Peter extending from the flood plain alluvium of the Meramec to the overlying Joachim and running around three sides of a prominent spur of the St. Peter-Joachim escarpment which projects south from the front of the much-dissected ridge. The width of outcrop is from 100 yards to ¼ of a mile. The quarry is located at the extreme southern point of the spur. The overburden is all Joachim limestone varying from 10 to 30 feet and averaging about 20 feet. The thickness of the limestone cover has forced the beginning of tunnel operations. The floor of the quarry lies above the flood plain sufficiently to make the pit self-draining. As all operations are by hand, no water supply is needed.

The work is both tunnel and open pit. The present face has an extent of about 300 feet and exposes 80 feet of sandstone.

The rock is drilled by hand, shot down and loaded by hand into wagons, and hauled to the station, where it is again shoveled by hand into the cars. The sand is not washed. The harder lumps are pounded up by hand, and the sand is hand-screened to take out the coarse, uncrushed fragments. The product from this quarry is used chiefly as moulding sand for steel casting, as core sand, and as furnace sand.

Glaser, J. W.—Mr. Glaser's quarry is located on the same cliff as that of the Tavern Rock Sand Company's quarry just described. In fact the two quarries are practically continuous and are operated in the same manner (Pl. XXIX, A). Mr. Glaser has a slightly lighter overburden to handle, and he does no tunnel work. He has at times also operated a much smaller sand pit, situated a little to the west of this one.

Favorable localities.—Most of the really favorable localities in this County are already occupied. The bluffs in the vicinity of Grays Summit are fairly well located as to transportation facilities. The sandstone, however, is usually exposed in slopes rather than in steep cliffs, and is generally ferruginous on the outcrop.

Near Becker in the NW. ¼ sec. 15, T. 44 N., R. 2E., is an abandoned quarry of the St. Peter, immediately adjacent to the right of way of the Chicago, Rock Island and Pacific Railway. The quarry is well located with respect to transportation and water supply facilities. The face of the sandstone, which is over 75 feet high and 200 feet long, is exposed, showing limestone and loess cover from 10 to 40 feet thick and increasing rapidly into the bluff. The pit extends 25 feet below the level of the track. Some tunnel work has been done. Except for the thick cover all the conditions are favorable to quarry operations. Herewith is presented an analysis of a typical sample (No. 45) of the white sand from the quarry face.

Analysis of St. Peter sandstone from Becker.

SiO_2	99.40
Al_2O_3	0.08
Fe_2O_3	0.05
CaO	0.16
MgO	0.08
Ignition loss	0.19
	99.96

A. J. W. Glaser's quarry, Pacific, Franklin County. St. Peter sandstone.

B. Quarry of Tavern Rock Sand Company, Klondike, St. Charles County. St. Peter sandstone.

ST. CHARLES COUNTY.

Distribution.—About 11 square miles in the County are immediately underlain by the St. Peter. The area lies in the extreme southwest corner of the County in a very irregularly dissected escarpment and extends westward from about two miles east of Klondike to the County line on the west. An inlier of the formation is also exposed in the vicinity of Schluersburg, where Femme Osage Creek and its tributaries cross the crest of a monocline with northwest-southeast axis (See map, Pl. XXX.)

Outcrops.—In the vicinity of Klondike, where the escarpment immediately overlooks the Missouri, the formation is exposed in bold cliffs. Westward, the escarpment rises considerably, passes away from the river front, and overlooks the northern edge of a shelf of the Jefferson City which intervenes between the main ridge and the river. Although this portion of the ridge is everywhere characterized by steep slopes, cliffs are not common. Gentle or only moderately steep slopes rather than cliff exposures are also the rule along the Femme Osage. This is due in part to the masking effect of deep loess deposits along the Missouri.

Character of the formation.—The sandstone consists of medium-fine, well-rounded and polished grains of very pure quartz. Low flat ledges, from which the protective cover of Joachim limestone has been removed and which are covered with ferruginous soil, show a crust of iron-stained sand. This is well shown near the lower central portion of the Klondike quarry. Where exposed in natural cliffs, the sandstone weathers gray to white, and shows very white in the quarry face. It is a moderately friable sandstone, though the same irregularity in distribution of the harder and softer phases is shown in this County as elsewhere.

Thickness.—Crane reports a measured thickness of 105 feet at the Klondike quarry, and the writer measured a section in the E. ½ sec. 4, T. 44 N., R. 1 E., that shows 100 feet of the sandstone.

Plants operating in the County.—There is only one plant, the Tavern Rock Sand Company, which operates in this county. Its quarry is at Klondike.

Tavern Rock Sand Company.—This company also operates a quarry in Pacific, Franklin County, and one just east of Pacific

in St. Louis County. The quarry is in the SW. ¼ SE. ¼ sec. 7, T. 44 N., R. 2 E. The office address is St. Louis.

The sandstone consists of very pure quartz in medium fine, well-rounded and polished grains. Herewith is given an analysis of the unwashed sand, average quarry run (Sample No. 77.)

Analysis of St. Peter sand from Klondike Quarry.

SiO_2	99.700
Al_2O_3	0.013
Fe_2O_3	0.057
CaO	0.060
Mg O	0.070
Ignition loss	0.100
	100.000

Wherever the overburden of the quarry is soil resting directly on the sandstone, there is a marked ferruginous crust which varies from two inches to three feet or more. The upper 20 feet are stained a very light pink or brown. This sand is kept separate in quarrying, and goes into foundry sand rather than into the product for the glass factories. Occasional limonite concretions are found, but these are separated in the screening. Bedding is more distinct than cross bedding, and is marked by the slight reddish or greenish discoloration noted in most of the quarries.

The whole section of the St. Peter is here exposed in the bluffs on the north side of Missouri River. The base of the formation, which rests on the Jefferson City dolomite, is about 120 feet above the river, and there is about 100 feet of sandstone capped with Joachim exposed in a cliff. The belt of sandstone is from 25 yards to ¼ of a mile wide, and the escarpment which here runs nearly east and west and faces south toward the Missouri River lowland is so deeply dissected that it has many bold salients and sharp re-entrants. The quarry is located on the southeastern end of one of the most prominent of these salients, where it has recently been undercut by the river, forming cliffs or very steep slopes (Pl. XXIX, B). Just at the point where the quarry is located, a notch in the ridge has removed the Joachim for a short distance, leaving an outlier of it on the extreme eastern end of the ridge. Quarrying began in this low saddle where there was no limestone cover, and has extended into the hill both east and west. Near the center of the quarry in the low saddle, the overburden is all loess and

ranges from 1 to 10 feet thick. On the eastern and western bluffs, there is both limestone and loess cover in varying proportion up to 30 feet and averaging about 15 feet.

The working face is over 1000 feet in length and varies in height from 20 to 100 feet. The full thickness of the sandstone is quarried, the floor of the quarry being practically the irregularly unconformable surface of the Jefferson City dolomite. The limestone overburden is broken up by blasting, loaded by hand into cars, and carried by aerial tram to the foot of the bluff and dumped (Pl. XXV, B). The work is all open pit. Drilling is done by compressed air; the sand rock is blasted down and loaded by steam shovel into quarry cars. Haulage is by mules to the central switch, then by drum and cable into the plant.

The mills are located on the steep slope below the quarry floor and above the Missouri, Kansas and Texas Railway, so that practically all the handling is by gravity (Pl. XXVII, B). The rock is crushed in Gates Gyratory crushers, dried in rotary drums, screened, elevated to bins, and loaded into the cars through chutes.

The output is used largely for glass making, moulding sand for steel casting, and for core sand. The capacity of the plant is 800 tons in ten hours.

Favorable localities.—Near the center of sec. 12, T. 44 N., R. 1 E., recent road excavations show that the sandstone, though slightly ferruginous on the outcrop, is very white in mass. Steep cliffs at this point offer favorable topographic conditions, except that heavy limestone cover would be reached in a short distance. The point is over half a mile from the railroad and would be difficult to reach. Many of the steep slopes of the sandstone escarpment north and northwest of Augusta, though slightly iron-stained on the surface, would probably yield white sand if opened up. Many of these ridges are favorably located topographically, but are from one to three miles from the railroad and through rugged intervening country.

WARREN COUNTY.

Distribution.—About 25 square miles in Warren County are immediately underlain by St. Peter. Although the outcrop in this region averages less than ½ of a mile in width, the deep dendritic dissection produces a belt from 8 to 10 miles wide over which the formation outcrops in all the deeper valleys. The escarpment follows closely the course of the Missouri,

but usually about a mile north of the river cliffs, a shelf of the Jefferson City intervening. The ridge is very irregularly dissected, and north from the escarpment long branching outcrops of the sandstone follow far up the stream courses. This belt occupies a strip about 10 miles wide along the Missouri entirely across the southern part of the County. In sec. 7, T. 46 N., R. 4 W., Crane maps an inlier of the St. Peter extending westward into Montgomery County. It lies along Little Bear Creek where that stream cuts across the crest of a slight anticline (see map, Pl. XXX.)

Outcrops.—Both along the escarpment proper and in the deep, branching re-entrants cut by the many streams, steep slopes of the St. Peter are the rule and there are cliffs at numerous points. Cliffs, however, are not so prominent a feature in Warren County as they are in Jefferson and northern Ste. Genevieve. Broadhead[1] reports especially good cliff exposures along Charette and Tuque Creeks.

Nature of the formation.—The sandstone shows the usual St. Peter characteristics of very pure quartz grains of medium size, well-rounded and polished. For the reason that the formation seems on an average to be more friable in this County than in any other on the belt, it was difficult to collect coherent samples, especially of the whiter phases. Although showing ferruginous stain at many points on low flat outcrops, much of the sandstone is gray to white where the outcrops are steep or cliff-like. Most of the ledges sampled in the County show a rather dirty grayish-white, and are not as clear and clean looking as at Klondike, Pacific and Crystal City. It is possible that this dirty, grayish appearance is superficial, and that strictly fresh exposures would show material as clean and white as that reported at other points.

Thickness.—Crane, who did the detailed mapping of the St. Peter north of Missouri River, reports twenty-one measured sections of the sandstone in Warren County, all of which are believed to show the total original thickness. The least thickness reported was 50 feet, the greatest 135 feet.

Favorable locations.—Near the center of sec. 32, T. 46 N., R. 2 W., a steep slope and cliff expose 60 feet of St. Peter sandstone. Topographic conditions are favorable to quarry operations, except that a thick cover of limestone would obtain. The

[1]Broadhead, G. C., Reports on the Geological Survey of the State of Missouri, pp. 54-55, 1873.

outcrop is 4 miles from the railroad, and rather rugged country intervenes. The sandstone shows the dirty gray-white color which is found so prominently over this County.

Near the center of sec. 1, T. 45 N., R. 3 W., a grayish-white sandstone similar to the above is exposed in a 50-foot cliff, much of which would have only a light soil cover. Topographic conditions are favorable to the opening of a quarry, but the locality is about 4 miles from a railroad and the country rough.

Analysis of St. Peter sandstone (Sample 83) from Warren Co.
(Sec. 1, T. 45 N., R. 3 W.)

SiO_2	99.570
Al_2O_3	0.065
Fe_2O_3	0.085
CaO	0.080
MgO	0.090
Ignition loss	0.140
	100.030

Broadhead[1] describes 60 and 80-foot cliffs of the sandstone in sec. 25, T. 46 N., R. 2 W., on Charette Creek, and also cliff-like exposures on Tuque Creek. Crane describes an 80-foot cliff of good white sandstone in the NW. ¼ sec. 20, T. 46 N., R. 2 W., on the dry fork of Charette Creek. These latter exposures were not visited by the writer nor were they sampled. They are from 5 to 8 miles from the railroad.

The whole belt in this County lies from 1 to 10 miles from the Wabash Railroad on the north and from the Missouri, Kansas and Texas Railway on the south. As most of the area has a moderately rough topography, the building of spurs would be difficult. Owing to the lack of transportation, there is little immediate prospect of the development of the glass sand industry. There are at present no sand plants in the County operating in the St. Peter.

MONTGOMERY COUNTY.

Distribution.—The St. Peter occupies about 21 square miles in that part of Montgomery County lying south of Danville. As in Warren County, the actual outcrop occupies a very narrow belt, averaging less than one-half mile in width, but the distribution is even more irregular than in Warren. The escarpment effect, though not wholly lost, is much obscured by the deep

[1]Broadhead, G. C., Reports on the Geological Survey of the State of Missouri, pp. 54-55, 1873.

dissection of the Loutre and its tributaries, with the result of typical dendritic outcrop in practically flat-lying rocks. An anticline with a nearly east-west axis passing through Mineola also exposes inliers of St. Peter and Jefferson City at the village of Mineola, where these formations are cut across by the Loutre and its tributaries (see map, Pl. XXXI).

Outcrops.—Over most of the area exposures occur along steep slopes, though, as in Warren County, actual cliffs are not so marked a feature of the outcrop as where the escarpment is more prominent, as, for instance, between the Missouri, and Establishment Creek in northern Ste. Genevieve County. Outcrops are abundant along the belt at most points.

Character of the formation.—The formation is a very pure, white, friable quartz sandstone with well-rounded and polished grains of medium to fine size. As in the other counties, where it is exposed on gentle slopes in low outcrops, it is usually very highly iron-stained; but on steep slopes it more often shows gray, while freshly carved overhanging cliffs are very pure white. Although on the whole the sandstone is very friable, there are noticeable differences in the degree of induration. These, however, seem to be without regularity.

Thickness.—Of thirty sections given by Crane showing what is believed to be the total original thickness of the formation in this County, the maximum is 100 feet and the minimum 10 feet. There seems to be a much greater irregularity in the thickness of the formation in this area than elsewhere, and it does not average as thick as in other counties, about 40 feet being a fair general estimate for Montgomery.

Favorable localities.—On the point of the bluff just west of Americus, near the center of sec. 2, T. 46 N., R. 6 W., moderately steep slopes expose between 30 and 50 feet of fairly white sandstone. Topographic conditions are suited to quarrying, and cover would not be excessive. The location is 5 miles from the nearest railroad and over rough country. An analysis of a sample (No. 91) from the ledge follows:

Analysis of St. Peter sandstone from Americus.

SiO_2	99.640
Al_2O_3	0.063
Fe_2O_3	0.097
CaO	0.030
MgO	0.010
Ignition loss	0.150
	99.990

In the NW. ¼ sec. 36, T. 47 N., R. 6 W., a cliff exposes a maximum thickness of 40 feet of good white sandstone. Topographic conditions are favorable to quarrying, except that there would be a moderately heavy limestone cover. The location is about 6 miles from the nearest railroad. The following is an analysis of the typical sandstone exposed (Sample No. 93).

Analysis of St. Peter sandstone north of Americus.

SiO_2	99.54
Al_2O_3	0.13
Fe_2O_3	0.07
CaO	0.06
MgO	Trace
Ignition loss	0.18
	99.98

At present, lack of transportation makes impossible any development of the glass sand industry along the St. Peter belt in this County, and there are no plants now operating on the sandstone. However, should a railroad ever go up the Loutre Valley, it might give value to the deposits described and to others in the vicinity.

LINCOLN COUNTY.

Distribution.—About seven square miles of Lincoln County are immediately underlain by St. Peter sandstone. Along the north side of the Cap au Gres fault, in Tps. 49 and 50 N., R. 2 E., west of Foley, there is a small compact area of the formation which dips to the northwest with irregular, branching outcrops. These outcrops run northwestward up the creeks a short distance and dip below the overlying Joachim. The same fault and accompanying folding expose very small patches also along creeks near Silex and Whitesides in secs. 4, 5, 8, 27 and 33, T. 51 N., R. 1 W. (see map, Pl. XXXII).

Outcrops.—Over most of this area exposures are low and flat, although prominent cliffs are exposed along a picturesque gorge through sec. 3, T. 49 N., R. 2 E. Cliffs are also to be seen along Mill Creek in sec. 28, T. 51 N., R. 1 W.

Nature of the formation.—The St. Peter in this County is a friable sandstone, consisting of moderately fine, well-rounded grains of very pure quartz. For the most part, the exposures show a heavy red or yellowish ferruginous stain, presumably owing to the leaching of iron-bearing solutions from red soils above. A well on the farm of D. B. Trower in the NE. ¼

sec. 10, T. 49 N., R. 2 E., passes through about 100 feet of the sandstone, all of which is highly iron-stained from top to bottom. The well is located almost on the line of the Cap au Gres fault, and the unusual degree of discoloration is believed to be due to the fact that the fault, having shattered the protecting Joachim cover, allowed unusual leaching down of ferruginous solutions long before erosion had uncovered the sandstone. On the Illinois side of the Mississippi just across from Winfield, and north of, but slightly removed from the fault, steep cliffs of the sandstone with protective Joachim cover are very white. These Illinois cliffs have in the past furnished glass sand for Alton plants. Cliff exposures in the northwest part of the County on Mill Creek, in secs. 28 and 33, T. 51 N., R. 1 W. show the usual degree of whiteness and purity found in cliffs of the formation at other places. Herewith is given an analysis of the average red sandstone from this County (Sample No. 70).

Analysis of ferrugin us St. Peter sandstone from Lincoln County.

SiO_2	96.65
Al_2O_3	1.17
Fe_2O_3	0.94
CaO	0.19
MgO	0.10
Ignition loss	0.84
	99.89

Thickness.—Between West Point and Dogtown, in Illinois, Weller[1] reports a thickness of 150 feet of the sandstone exposed in almost vertical bluffs, the full section being present. Potter[2] reports a section just south of Foley where the total thickness does not exceed 65 feet.

A well in the vicinity started and bottomed in the St. Peter cuts 80 feet of sandstone.[3]

Favorable localities.—The sandstone exposed in the area near Winfield and Foley is all highly ferruginous, and no exposures were seen which were suitable for glass sand. More suitable sandstone for this purpose is exposed in several small patches near Silex.

In the SE. ¼ SW. ¼ sec. 28, T. 51 N., R. 1 W., along the south side of Mill Creek, are exposed 30-foot cliffs of good white sandstone. The rock is unusually friable and is very uniform

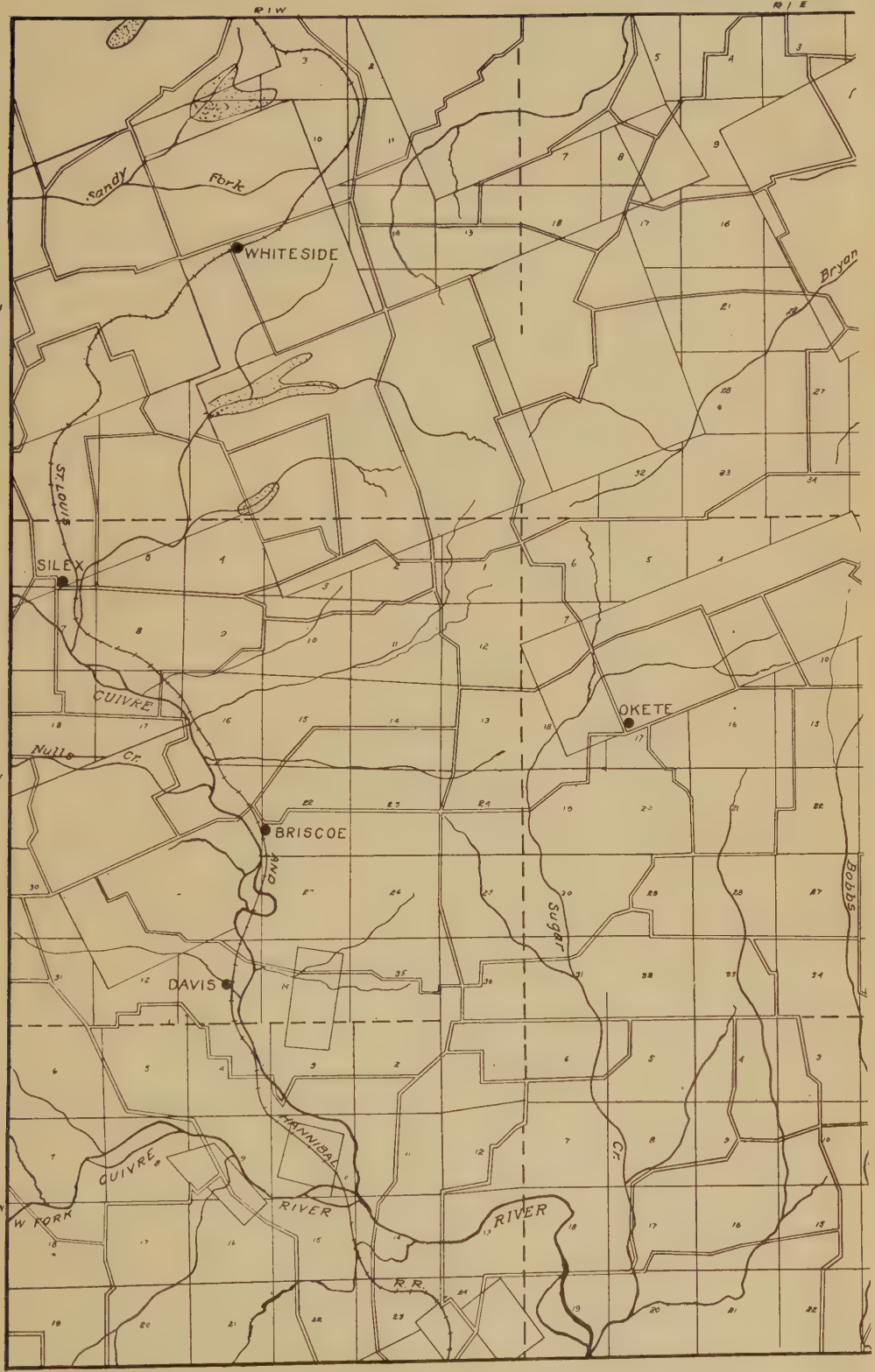
[1]Weller, Stuart, Bull. Geol. Surevy of Ill., No. 4, p. 221, 1907.

[2]Potter, B. W., The Geology of Lincoln County; Geological Survey of Missouri; Iron Ores and Coal Fields, pt. 2, p. 224, 1872.

[3]Wilson, M. E., Personal communication.

Map of part of

LINCOLN COU



INTY

s in Miles

3 1 5

St Peter Sandstone

and white. The cover of Joachim limestone is from 1 to 5 feet thick at the edge of the cliff, and increases rapidly into the bluff until it attains about 15 feet at from 50 to 150 yards back. It then thickens gradually to about 30 feet under the cultivated fields to the south. Except for the thick cover, topographic conditions are very well-suited to the opening of a quarry. The sandstone probably extends considerably below the valley bottom, and being so unusually friable, it might possibly be pumped out, as it is at Ottawa, Ill.[1] This exposure is 3 miles from the St. Louis and Hannibal Railroad and is over flat bottom lands the entire distance. The cliffs grow lower eastward up the creek owing to the dip of the beds. An analysis was made by the chemist of this Survey and is given below (Sample No. 75).

Analysis of St. Peter sandstone from near Silex.

SiO_2	99.26
Al_2O_3	0.07
Fe_2O_3	0.11
CaO	0.15
MgO	0.07
Ignition loss	0.21
	99.87

Near the center of the SW. ¼ sec. 33, T. 51 N., R. 1 W., on the north side of the creek, is a good cliff of very white sandstone, considerably harder than that just described. Twenty feet is exposed in the cliff face, and perhaps 20 feet more in a gradual slope above the cliff. The Joachim is completely removed, and the soil cover varies from a few inches up to 3 or 4 feet. A thin crust at the surface is iron-stained, but where recent undercutting has caused caving and fresh exposure, the sandstone is very white. Topographic conditions are favorable to quarry operations. The bluff is about 2 miles from the St. Louis and Hannibal Railroad. An analysis by Chauvenet[2] is presented below.

Analysis of St. Peter sandstone fron near Silex.

Silica	99.55
Alumina	0.33
Iron	Trace
Lime	0.08
Water	0.015

This analysis shows a sand suited for the better grades of plate glass.

[1]Burchard, E. F., Mineral Resources of the United States for 1911, pt. 2, p. 598.
[2]Geological Survey of Missouri, Iron Ores and Coal Fields, pt. 2, p. 289, 1872.

SANDSTONE OF DOUBTFUL AGE, LITHOLOGICALLY RESEMBLING THE ST. PETER.

Between North Jefferson and Holt Summit in Callaway County, at Clifton in Cooper County, and at Sedalia in Pettis County, there are deposits of white sand which are attracting attention. Samples of these sands have been submitted to this Bureau for examination. They closely resemble the St. Peter in lithologic character, having a high degree of purity and consisting of well-rounded grains of medium size with the frosted surfaces characteristic of St. Peter sands. They lie west of, and are isolated from, the main mass of the St. Peter belt, continuous exposures of which end near the east line of Callaway County. Detailed field evidence is not available for the dating of these sandstones, but they are probably either St. Peter or St. Peter worked over in a later period, possibly the Devonian or Carboniferous.

Along the line of the Chicago and Alton Railroad on the property of N. W. Bedsworth, about midway between North Jefferson and Holt Summit in Callaway County, occur a group of these exposures, showing about 35 to 40 feet of sandstone with only a thin soil cover. The sandstone is rather iron-stained on the surface of the outcrop, but a large test pit shows only a foot or so of stained sand, the deeper portions being very white. The ledge is immediately adjacent to the railroad track and on a hill slope which would give ready drainage. Water supply would have to be secured from a well. A typical sample (No. 241) selected from the test pit by the writer was analysed with the following results:

Analysis of sandstone from Holt Summit.

SiO_2	99.36
Al_2O_3	0.34
Fe_2O_3	0.10
CaO	None
MgO	Trace
Ignition loss	0.24
	100 04

In a recent letter to this Bureau, Professor Branson of the University of Missouri reports that this deposit is St. Peter sandstone.

The Sedalia Chamber of Commerce submitted washed samples of prospective glass sand to this Bureau for analysis. They showed the following composition:

Analysis of washed sandstone from Sedalia.

SiO_2	99.750
Al_2O_3	0.123
Fe_2O_3	0.057
CaO	None
MgO	None
Ignition loss	0.050
	100.010

The sand after being washed is sufficiently pure for plate glass. The ledge is located at Clifton in Cooper County and is reported to be extensive and easily accessible. It was not visited by the writer. There are reports of similar ledges on Flat Creek south of Sedalia in Pettis County. These outcrops were not visited, and it is not possible to state the age of the sandstone.

THE JOACHIM.

The Joachim formation is essentially a dolomite, but in Perry and Cape Girardeau counties, it carries thin sandstone lenses at the base just above its contact with the St. Peter. Screen tests were made on a few Joachim samples for comparison with the St. Peter (see table, p. 126). The lenses are thin, for the most part are of very fine grain, and are much more firmly indurated than the St. Peter. They can have no possible economic development.

THE PLATTIN.

This limestone is without important sandstone beds.

THE DECORAH.

This shale is also without important sandstone beds.

THE KIMMSWICK.

The Kimmswick limestone is practically without sandstone beds.

THE FERNVALE.

This formation, which is only three or four feet thick, is wholly limestone.

THEBES SANDSTONE.

This formation, called by Shumard[1] the Cape Girardeau Sandstone, has been described as having a very limited area of exposure in and about the city of Cape Girardeau. It is a fine-grained, yellowish, argillaceous sandstone, moderately friable. Shumard gives the following analysis:

Analysis of Thebes sandstone.

SiO_2	87.58
Al_2O_3 and Fe_2O_3	9.67
Lime not determined.	
H_2O	1.35

The total thickness is reported as about 100 feet. Owing to its discoloration and impurities, it has no value as a glass sand, and it is too fine-grained to have value as a building sand, especially when forced to compete with Mississippi River sand which is easily available at this point. There is no possibility of the development of the formation as a sand producer.

Shumard reports that the Thebes is probably not present in Perry County. Weller[2] reports it in Ste. Genevieve County. The formation seems to be absent in parts of the latter named County owing to later erosion, but reaches a maximum thickness of about 70 feet, of which 20 feet or less is sandstone. Its most prominent development is in the southern part of the County, where it is quarried as building stone. The sandstone is everywhere much discolored, is fine-grained, calcareous or argillaceous, and well cemented. It will probably never be a sand producer. North of Ste. Genevieve County, the Thebes, where present, is almost wholly shale.

THE CAPE GIRARDEAU.

No sandstone beds are reported in the limestones of this formation.

THE NOIX.

This formation consists of a few feet of oolitic limestone, with no sandstone beds.

THE BAINBRIDGE.

No sandstones of importance occur in this limestone

[1] Reports on the Geological Survey of the State of Missouri p. 264, 1873.
[2] Weller, Stuart, Unpublished manuscript.

THE BAILEY (INCLUDING CLEAR CREEK?).

This limestone is practically without sandstone beds, but is extremely cherty in the upper half; and this chert forms an abundant residual gravel.[1]

In Perry County, about three miles south of Wittenberg and only a short distance south and west of Tower Rock, a ballast pit of the St. Louis and San Francisco Railroad exposes a very heavily bedded chert formation. Not enough work was done in the area to warrant a definite statement as to the age of the cherts exposed beyond the mere fact that they are Devonian. Wilson[2] is of the opinion that they belong to the Bailey formation. Savage[3] describes Tower Rock and the adjacent quarry and cut as consisting of beds of the New Scotland formation. The ballast pit is a few rods southwest of the quarry and cut mentioned and is probably in the same formation. The formation is a heavily bedded massive chert, gray or yellowish on unweathered surfaces, but for the most part, in the pit itself it is leached to an extremely porous, almost pure white tripoli-like substance soft enough to be easily excavated with a steam shovel. These cherts fit Savage's description of the Clear Creek much better than they do his description of the New Scotland beds, and it is more than possible that a small area of the Clear Creek is exposed on the Missouri side of the river. From descriptions by Savage and by Weller,[4] it is possible that the Bailey, as the term is used by the latter writer, includes both the New Scotland and the Clear Creek, as these terms are used by Savage.

Since these cherts result from the weathering and leaching of the Devonian rocks, they possibly should be treated under recent formations; but as they are quite different from the ordinary residual flints from the surface weathering of cherts or cherty limestones, it seems advisable to discuss them under the formation from which they are derived.

The pit is situated in Perry County about three miles south of Wittenberg, just below Tower Rock, and about midway between the stations of Wittenberg and Gerler on the St. Louis and San Francisco Railroad. The workings, the writer was told, formerly consisted of two small tunnels driven into the

[1] Wilson, M. E., Unpublished manuscript.
[2] Personal communication.
[3] Bull. Geol. Survey of Ill., No. 7, p. 112, 1907.
[4] Weller, Stuart; Unpublished manuscript.

hillside adjacent to the right of way. Considerable material, locally known as silica, was taken out and shipped to St. Louis for use in the ceramic industries.

At present, the tunnels are abandoned and all evidences of them obliterated. The entire side of the hill is being cut away by steam shovels. The working face is several hundred feet long and varies from 20 to 75 feet in height. The overburden is loess and varies from a few inches to ten feet or more.

The bluffs from near the Tower Rock south three or four miles to Gerler consist of thin to heavily bedded chert, yellowish, brownish and gray on the unleached outcrop. The chert is much brecciated and at Gerler it is seen to rest with uneven (possible unconformable) contact on cherty limestones. Throughout this distance the chert shows leaching at various points, but only near the pit is this leaching of extreme character.

In the pit the cherts are leached to white, porous masses which in places become true tripoli, though for the most part the material is still harder than tripoli. The mass is soft enough to be dug out easily with a pick and is handled directly with a steam shovel.

The bedding in the pit is uneven, curving downward toward the center as if from slump (see Pl. XXXIII, A).

Ravines extending back into the bluff show the same leached and decayed chert scattered for a considerable distance over the slopes. This decayed chert is being extensively used as ballast along the Frisco line and is said to be satisfactory. Occasional shipments of the whiter, softer material are being made to St. Louis where it is used in the ceramic industry.

THE LITTLE SALINE.

This formation contains no sandstone beds of importance.

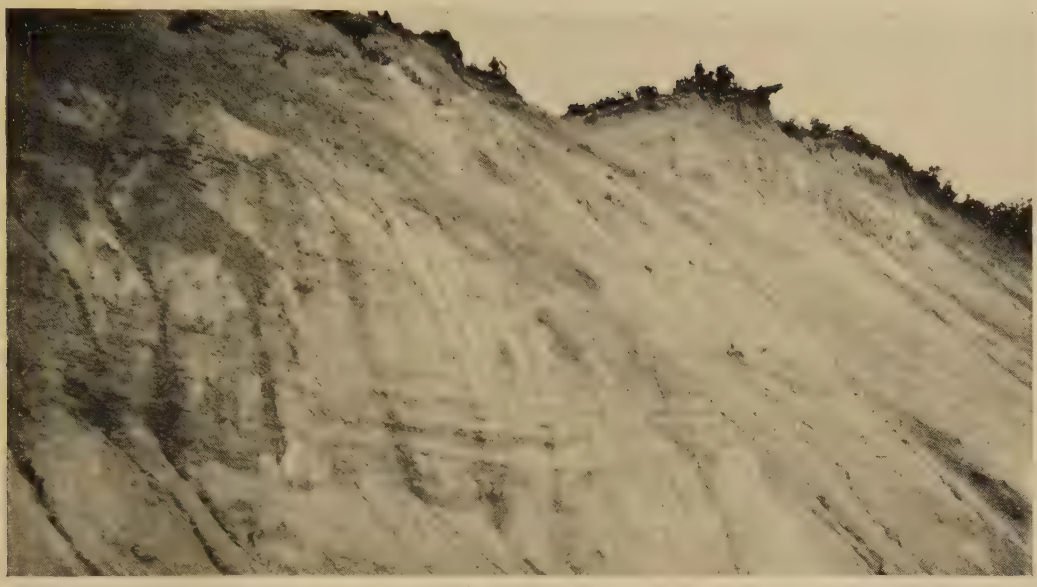
GRAND TOWER.

According to Wilson[1] this limestone contains impure sandstone beds near the base, but nothing of any possible significance as a sand producer.

BEAUVAIS SANDSTONE.[2]

So far as is known, this formation occurs over a very limited area, chiefly in the faulted zone of the southern part of

[1] Unpublished manuscript.
[2] Weller, Stuart, unpublished manuscript.



A. Ballast pit in tripolitic chert, Wittenberg, Perry County. Curved strata show slump.

B. Pit of Pacific Cement Gravel Company, Pacific, Franklin County. So-called Lafayette red gravel.

Ste. Genevieve County. In its lithologic characteristics it very closely resembles the St. Peter, from which it is distinguished with difficulty and for which it has frequently been mistaken. It is supposed to be derived from the St. Peter and worked over in the Devonian sea. The rock consists of a very pure quartz sand of medium grain, the component grains being well rounded. For the most part it is very white and moderately friable, though at places it becomes stained and indurated. No single section exposes more than 50 feet of the sandstone, the best exposure being on the south bank of the Little Saline, a quarter of a mile east of the Boarman School road. It is possible that with good transportation facilities this might prove a good glass sand. At present it is valueless.

THE ST. LORENZ.

This limestone has a few thin sandstone layers, but none of possible importance in the production of sand.

THE CHATTANOOGA.

This shale formation has no sandstone of any possible commercial value.

OTHER DEVONIAN SANDSTONES.[1]

At places in Warren, Montgomery, Callaway, Moniteau, and adjacent counties, thin sandstones occur that have been described as Devonian. As a rule, they are only a few inches to a few feet thick, but because of unconformities both above and below, they occasionally thicken to as much as 60 feet. In the same counties and in adjacent areas detached patches of sandstone have been variously placed in the St. Peter, the Devonian, and the Pennsylvanian. Most of these detached areas may never be positively identified. The exact horizon of the so-called Devonian of this region has not been determined, and it is not yet possible to correlate it with other areas of the Devonian in this or nearby States. It is possible that these are the equivalent of the Phelps described on a later page.

The so-called Devonian sandstone of the area described above probably has no economic value whatever.

[1] Branson, E. B., Devonian Fishes of Missouri, The University of Missouri Bulletin, vol. 15, No. 31, Science Series, vol. 2, No. 4.

Van Horn, F. B., and Buckley, E. R., Geology of Moniteau County, Missouri Bureau of Geology and Mines, vol. 3, 2d series, pp. 38-43.

A Devonian sandstone of undetermined horizon is reported[1] in Jefferson County at Sulphur Spring, and near the mouth of Rattle Snake Creek. It averages about 8 feet in thickness, but in sec. 12, T. 43 N., R. 4 E., it is said to reach a thickness of 20 feet. It is a brown quartzose sandstone of no possible value for sand. This is perhaps early Kinderhook[2] and is possibly the equivalent of the Phelps.

THE GRASSY CREEK.

This shale carries no important sandstone beds.

THE LOUISIANA.

The Louisiana limestone contains practically no sandstone.

THE HANNIBAL (INCLUDING THE VERMICULAR SANDSTONE).

This formation, which is dominantly shale, carries heavy sandstone beds at a few points. These were known to the older writers as the Vermicular sandstone. Rowley[3] reports that in Pike County, where the Vermicular sandstone is typically developed, it is a "few feet of yellow sandstone—of no economic value, whatever." It is reported to be of similar character in Marion County,[4] while in Cooper County[5] the Vermicular horizon is reported to contain no sandstone whatever.

In Lincoln County,[6] the Vermicular contains about 13 feet of very shaly sandstone. In Cedar County[7] it is said to be a "buff brown, very fine-grained and sometimes calcareous sandstone." It is reported to occur on the higher divides in Wright County, where Shumard[8] describes the upper part as a "soft, buff Calcareo-magnesian Sandstone, perforated with Vermicular cavities." This latter occurrence is quite probably the equivalent of the Northview sandstone reported in Wright, Webster and Greene counties, where it is said by Wilson[9] to be of probable Chouteau age.

---

[1]Shumard, B. F., Reports of the Geological Survey of the State of Missouri, p. 306, 1873.
[2]Weller, Stuart, Unpublished manuscript.
[3]Rowley, R. R., The Geology of Pike County, Missouri Bureau of Geology and Mines, 2d Series, vol. 8, pp. 32-33, 1907.
[4]Swallow, G. C., First and Second Annual Reports of the Geological Survey of Missouri, p. 176, 1855.
[5]Swallow, G. C., op. cit., p. 195.
[6]Potter, B. W., The Geology of Lincoln County; Geological Survey of Missouri; Iron Ores and Coal Fields, pt. 2, p. 245, 1872.
[7]Broadhead, G. C., Report of the Geological Survey of the State of Missouri, including field work of 1873-1874, pp. 66-67, 1874.
[8]Shumard, B. F., Reports on the Geological Survey of the State of Missouri, pp. 206-207, 1873.
[9]Wilson, M. E., Unpublished manuscript.

THE PHELPS.

This sandstone, which occupies in southern and western Missouri a stratigraphic position near that of the Hannibal shale in the northeastern portion of the State, is reported by Shepard,[1] to occur in Greene County, where it varies from a pure quartz sandstone resembling the St. Peter to a coarse conglomerate, the maximum thickness of the formation not exceeding four feet in that County. Wilson[2] reports that the Phelps, though known over a fairly wide area, is very patchy in distribution, and rarely exceeds a few feet in thickness, though locally, in a well at Concordia (Lafayette County), it thickens to about 60 feet. It closely resembles the St. Peter in character, being distinguished from that formation with difficulty, especially in cuttings. Its outcrop is not extensive, and owing to its patchy distribution and its thinness, it probably has no value as a source of sand, even though it appears to approach the requisite degree of purity. This is probably the equivalent of a portion at least of those beds already referred to under the heading, "Other Devonian Sandstones."

THE CHOUTEAU (INCLUDING THE NORTHVIEW).

In its type locality the Chouteau contains little or no sandstone, but in southwest Missouri, certain shales and sandstones long correlated with the Hannibal are believed to be of Chouteau age. They have been called by Moore[3] the Northview formation. They are typically exposed in Wright, Webster, and Greene Counties, where they reach a maximum of 60 feet, only part of which, however, is sandstone. They are probably the equivalent of what Shumard[4] has called the Vermicular sandstone in Wright County. They are said by Wilson to be the exact counterpart in lithologic character, of the "Vermicular" horizon of the Hannibal, and if this is the case, they probably offer no possibility of commercial development.

THE FERN GLEN.

This is a very thin formation with no sandstone of possible commercial value.

---

[1]Shepard, E. M., A Report on Greene County, Geological Survey of Missouri, vol. 12, pt. 1, pp. 77-82, 1898.

[2]Wilson, M. E., Unpublished manuscript.

[3]Moore, R. C., Unpublished manuscript.

[4]Shumard, B. F., loc. cit.

THE BURLINGTON AND KEOKUK (INCLUDING THE BOONE).

These formations, which consist of very cherty limestones, contain no sandstones of importance. Residual flint beds, the so-called hard-pan gravels, afford road metal derived from this formation at a few points. It is of local importance only.

THE WARSAW.

The Warsaw limestone and shale contains no sandstone members of importance.

THE SALEM.

This formation is chiefly limestone and carries no important sandstone beds.

THE ST. LOUIS.

No sandstone beds of importance are found in the St. Louis limestone.

THE STE. GENEVIEVE.

The Ste. Genevieve limestone is also devoid of sandstone beds of any importance.

THE AUX VASES.

This, at least in part, is the "Ferruginous Sandstone" of the earlier writers, and is well developed in Perry and Ste. Genevieve counties. In the latter County[1] it occurs in a narrow belt, beginning 1½ miles below the city of Ste. Genevieve and extending southeast into Perry County. In Perry County one of the most conspicuous outcrops is a bold cliff along the river bluff, about ½ mile below McBride, in the SE. ¼ of the NE. ¼ sec. 17, T. 36 N., R. 11 E. Shumard[2] reports that it occurs in numerous places in the northern part of Perry, that it outcrops along Bois River, and that it is prominent along the "river bluffs" north of Wittenberg. In Ste. Genevieve County it is reported by Weller to be a fine-grained, even-textured, well-indurated sandstone of a pale yellowish color, slightly argillaceous at places. The maximum thickness in this county is about 60 feet. It is used as a building stone, but probably is too firmly indurated to be of value for sand.

[1]Weller, Stuart, Unpublished manuscript.
[2]Reports of the Geological Survey of the State of Missouri, p. 279, 1873.

In Perry County the sandstone reported as the "Ferruginous Sandstone" by Shumard may, in part, be the sandstone member of the Renault. He describes it as firmly cemented in a few places only, being for the most part rather friable. The color is reported to vary from white to brown. The exposure visited by the writer in the SE. ¼ of the NE. ¼ sec. 17, T. 36 N., R. 11 E., about half a mile southeast of McBride, is a pale yellow or cream-colored stone, rather fine-grained, very firmly cemented and slightly calcareous. It rests with evident unconformity on the Ste. Genevieve limestone. The cliff exposes between 40 and 60 feet of the formation, which is overlain by a heavy cover of loess. Along the face of the exposure is an abandoned quarry. The cliff borders the right-of-way of the St. Louis and San Francisco Railroad, thus making shipping facilities excellent.

A mechanical analysis of the Aux Vases sandstone is given on page 126 (sample No. 135). The analysis is not entirely to be depended upon, inasmuch as the sandstone is so well cemented that it is extremely difficult to crush a sample for screen tests without leaving a great many unseparated aggregates of grains. This adds unduly to the coarser sizes, and at the same time crushes certain grains which increases the fines beyond their probable true proportion.

Herewith is given a chemical analysis of the same sand (sample No. 135.)

Analysis of Aux Vases sandstone.

SiO_2	94.80
Al_2O_3	0.51
Fe_2O_3	0.02
CaO	2.07
MgO	0.12
Ignition loss	1.90
	99.42

The analysis shows a content of iron sufficiently low for a glass sand, though alumina runs near the maximum limit.

This sandstone is much more firmly cemented than the average of those used for glass sand throughout the country, and although the outcrop is very favorably located with respect to transportation, it will probably not be used as a source of glass sand.

THE RENAULT.[1]

This formation, so far as is known, is limited to southeast Missouri, and has been mapped only in Ste. Genevieve County. The formation has a very limited outcrop between the mouth of Aux Vases Creek and the Perry County line. It contains not over 20 feet of sandstone, fine-grained, yellow-brown and moderately well cemented. This formation may include portions of what in other counties was called the "Ferruginous Sandstone" by the older geologists.

The formation has no possible value as a sand producer.

PENNSYLVANIAN SYSTEM.

PENNSYLVANIAN SANDSTONES OF THE OZARK REGION.

Throughout many counties of the Ozark region, isolated masses of Pennsylvanian sandstone are well known. They occur abundantly along the divide between Meramec and Bourbeuse Rivers in Phelps and Crawford counties and are reported from many other localities. They were mapped by the older geologists chiefly as the "First" or "Saccheroidal Sandstone" and it is wholly possible that some of these isolated patches may be the St. Peter. It is to be presumed that if they are Pennsylvanian, they contain much worked over St. Peter, and this renders their discrimination very difficult. The association of much of the sandstone with pockets of Pennsylvanian shale and fire clay, and even of coal, makes it probable that most of the outliers have been worked over during the Carboniferous period. Such outliers are reported from Miller County, and Buckley[2] gives a good discussion of their probable age.

At no point where the writer has observed these outliers is there any probability of their yielding sand suitable for glass making. For the most part, they are very irregular and pockety, associated with argillaceous phases and much too ferruginous to yield sand of any value. Occasional pockets of clean white sand have been observed closely resembling St. Peter, but they are always of small extent, and grade irregularly and suddenly into less pure material.

---

[1] Weller, Stuart, Unpublished manuscript.

[2] Missouri Bureau of Geol. and Mines, Vol. 1, 2nd series, p. XII-XIV of the introduction, 1903.

In Miller and Morgan counties, of which detailed reports are available, and in Phelps County, where the present writer has studied these outliers with considerable detail, there seems little probability of their ever having any economic value. Outside these areas, not enough detailed evidence is available to make a definite statement possible, but it is probable that Ozark Pennsylvanian has no value as a sand producer.

PENNSYLVANIAN SANDSTONES OF NORTHERN MISSOURI.

The following notes on the Pennsylvanian sandstones of the northern and western portions of the State were supplied by F. C. Greene who has done much work for this Bureau on the Pennsylvanian areas:

"Sandstone occurs throughout the Pennsylvanian area of the State. The principal sandstones of the series are the 'Clear Creek' member of the Cherokee formation which outcrops in Barton, Vernon, Cedar, St. Clair and Henry counties; the Warrensburg sandstone in Johnson, Lafayette and Carroll counties; the sandstone in the Lawrence shale in Platte and Clay counties; and the Pleasanton sandstone in Livingston, Linn, Grundy, Mercer, Sullivan, Putnam and Adair counties. In some places these beds are over 100 feet thick, but in others they range from a foot or less to over 50 feet.

"The common and prevailing type of Pennsylvanian sandstone is gray or bluish-gray, weathering to brown or yellowish-brown. The sandstones are very fine-grained, micaceous, fairly well cemented and contain more or less iron and clay, the 'Clear Creek' sandstone being the only known exception to these characteristics. Locally, the 'Clear Creek' is slightly coarser than the common type, of light gray to white color and loosely consolidated.

"In general the Pennsylvania sandstones of northwestern Missouri are valueless as producers of glass or building sand. The asphaltic sandstones of the Cherokee formation in Barton, Vernon, Bates and Lafayette counties may prove to be of value in road construction, but they have not been developed."

The following notes on these asphaltic sands have been furnished by M. E. Wilson, of this Bureau, except the Higginsville deposit, which is described by Mr. G. A. Muilenburg, also of this Bureau.

ASPHALTIC SANDSTONES OF THE PENNSYLVANIAN.

GENERAL.

Sandstones containing bitumen occur extensively in a number of western Missouri counties where the lower Pennsylvanian strata comprise the surface formations. These sandstones are generally known as asphaltic sandstones though

the bituminous matter contained is chiefly a heavy black crude oil rather than true asphalt. For many years interest has centered in them for their possible use as a road metal, though up to the present time all efforts to commercialize them for this purpose have failed. However, it is not improbable that in the near future some method of treatment may render them serviceable, when they may form the source of supply for an important industry.

LOCATION OF OCCURRENCES.

The occurrences of these bituminous sandstones are chiefly in Barton, Vernon, Bates, Cass, Lafayette and Cedar counties with probably lesser amounts in Jackson, Ray, Carroll, and Caldwell counties. Small outliers of the Pennsylvanian sandstones containing bitumen are also known to occur in Dade and Barry counties. So far as they have been studied the most extensive deposits are those of northern Barton and southern Vernon counties, though those of other counties may prove to be of almost equal extent upon further exploration. Even where extensive deposits occur the outcrops may be limited, and it is difficult to estimate the area underlain without prospecting. It may be said that the full extent of any of the occurrences where the sandstone lies close to the surface, is unknown, though it is certain that in parts of Barton and Vernon counties the rock at different localities underlies large areas, and is found outcropping at widely scattered points. It is not unreasonable to suggest that in this area the extent of the bituminous sandstone, where it lies close to the surface, may be estimated in square miles.

GEOLOGY.

Geologically the bituminous sandstones occur in the lower Pennsylvanian formations and are known in the Cherokee shale, the Henrietta and Pleasanton formations and the Warrensburg sandstone. No important occurrences have been found in the upper Pennsylvanian rocks of Missouri, though bituminous limestones outcrop in Cass and Jackson counties in the Kansas City formations. The most extensive occurences of the bituminous sandstone are found in the Cherokee shale, but those of both the Pleasanton shale and Warrensburg sandstone are of very important size. Broadhead[1] stated that there were over

[1]Broadhead, G. C., Report of the Geological Survey of Missouri, p. 51, 1873-74.

600 feet of strata through which the bituminous sandstone occurred.

These sandstones lie in almost horizontal beds though they conform to the regional dip of the rocks in the area in which they are found. Generally this dip is low, not exceeding a few feet to the mile, and in a west or northwest direction. At many localities over considerable areas the beds are either exposed or lie very close to the surface. They are covered only by soil and clay or by easily removable shale.

THICKNESS OF BEDS.

The individual bituminized beds are of variable thickness and the sandstone is commonly not uniformly bituminized in vertical section at any locality, and the bitumen content varies appreciably between nearby points. A few miles east of Sheldon in southeast Vernon County, a maximum thickness of 30 feet of bituminous sandstone is reported. Northwest of Liberal, in Barton County, Broadhead[1] reports wells penetrating as much as 50 feet of the bituminous sandstone. Two miles north of Higginsville, Lafayette County, 15 to 20 feet of bituminous sandstone outcrops, and the maximum thickness, though unknown, is considerably greater. In southwest Ray County 15 feet of the material has been penetrated close to the surface. The Vernon-Barton County deposits are in the Cherokee shale, the Lafayette County deposits in the Warrensburg sandstone, and the Ray County deposits in the Pleasanton formation.

At very few localities is the maximum thickness of the bituminized beds known. It is safe to say, however, that considerable areas are underlain by them, close to the surface, where the rock exceeds a thickness of 10 feet, and probably 20 feet.

ACCESSIBILITY.

There are many localities where these bituminous sandstones occur close to or within a few miles of the railroad. They all occur in fairly level areas where the roads are good throughout the greater part of the year. Providing the deposits at a number of localities could be commercialized, the transportation problem could be easily disposed of. The greatest initial expense in obtaining the rock would be the cost of quarrying. In nearly all of the localities extensive quarrying could not be

[1]Broadhead, G. C., Report on the Geological Survey of Missouri, 1873-74; p. 115, 1874.

undertaken without some stripping. The amount of overburden to be removed may vary from 5 to 20 feet, constituted in some localities of only soil and clay and in other localities of some shale. However, providing the rock can be commercialized, the quarrying is a simple problem.

AMOUNT OF BITUMINOUS CONTENT.

The bituminous sandstone on fresh fracture is chocolate-brown to black in color, soft, and friable. The bitumen constitutes practically all of the cementing material and when removed the rock crumbles to a mass of blue sand grains. The sand grains are very fine to fine in size, angular, and composed almost wholly of quartz. Most of the rock is micaceous.

The bitumen is present in variable amounts, although the average for the different localities for which tests have been made is quite similar. From tests made at this Bureau the bitumen content has been found to run from 6.5 per cent to 15 per cent. Buckley[1] states that the percentage of bitumen in the stone frequently reaches 12 to 15 per cent. From an outlier of Pennsylvanian bituminous sandstone in Barry County a sample has been received by this Bureau which contained 6.5 per cent bitumen. A sample from Sheldon in Vernon County yielded 8.2 per cent of volatile matter, and by ether extraction, gave 7.45 per cent bituminous material. Two samples tested from the deposit near Sheldon, Vernon County, contain 7 per cent and 8.2 per cent bitumen. Samples tested at the U. S. Geological Survey from the Higginsville deposit[2] contain from 6 to 8.5 per cent bitumen. At the present time, however, there has not been a sufficient number of analyses made over wide enough areas, on the bituminous content of the sandstone, to be of practical value. A statement by Buckley that the percentage of bitumen in the rock frequently reached from 12 to 15 per cent was no doubt based upon a number of analyses made in 1904, but which are now not available. The bituminous content of the rock is very deceptive and the amount of bitumen present is commonly overestimated.

---

[1]Missouri Bureau of Geology and Mines, Forty-third Biennial report of the State Geologist, p. 36, 1905.

[2]Eldridge, G. H., The asphalt and bituminous rock deposits of the United States; Twenty-second Ann. Rept., U. S. Geol. Survey, pt. 1, pp. 259-261, 1901.

NATURE OF THE BITUMEN.

The bitumen present is without doubt the result of the inspissation of crude petroleum originally contained in the sandstone, through exposure and consequent evaporation. The composition of the material is therefore variable, from one locality to another and even in the same locality, depending upon the extent to which the original oil has been inspissated. Commonly the bitumen is of a thick black nature and in warm weather flows from the bedding planes and joint planes in the rocks to form "tar springs." The oil distilled from a sample of the sandstone from southeast Vernon County has a specific gravity of 0.915. In some localities small particles of true asphalt occur in the sandstones with a greater bulk of the bitumen a heavy black thick maltha. In most localities the bituminous matter is chiefly a heavy black viscous oil, which flows readily in warm weather. In the Lafayette County occurrence Broadhead[1] reports finding even thin amber colored oil together with heavy black oil and solid asphalt. Two analyses by this Bureau of the bitumen from localities in Vernon County where the rock very closely represents the greater amount available for practical use, show 10.5 and 12.5 per cent asphaltine and 87.5 and 89.5 per cent petrolene. Relative to the use of the natural rock crushed for paving, therefore, the fact that the bitumen contained is chiefly a petroleum rather than an asphalt must be borne in mind as an unfavorable factor. The percentage of asphaltine in these two analyses is much lower than the average of the analyses cited by Snider for the Oklahoma deposits, which run from 21 to 28 per cent (see page 68).

PHYSICAL CHARACTER OF THE SAND.

After removal of the soluble bituminous matter, a sample of this sand from Sheldon, Vernon County, was dried, and screen tests made on it. They are tabulated below.

---

[1]Broadhead, G. C., Geological Survey of Missouri, Iron Ores and Coal Fields, pt. 2, p. 41, 1872.

Screen analysis of asphaltic sandstone from Sheldon.

Thru.	On.	Per cent.	Screen.	Total thru.	Total on.
	20	0.00	20	100.00%	0.00%
20	40	2.58	40	97.42	2.58
40	60	8.55	60	88.87	11.13
60	80	42.73	80	46.14	53.86
80	100	3.40	100	42.74	57.26
100	120	34.18	120	8.56	91.44
120	200	5.55	200	3.01	96.99
200	Pan	3.01	Pan	0.00	100.00
		100.00			

This shows a sand with a large percentage of fines, passing the 100-mesh sieve. When studied under a magnifier, the sand is seen to be composed of practically pure quartz, the grains of which are remarkably angular, with many well developed crystal faces still preserved.

The description of the Higginsville deposit was prepared by G. A. Muilenburg and that of the Sheldon deposit by M. E. Wilson.

THE HIGGINSVILLE DEPOSIT.

This deposit of bituminous sandstone is exposed in a dry creek bed in the SE. ¼ sec. 36, T. 50 N., R. 25 W., and the NE. ¼ sec. 1, T. 49 N., R. 25 W., three-fourths of a mile northwest of Higginsville.

Stratigraphically it occurs in the Warrensburg sandstone of the Pennsylvanian.[1]

In the right hand bank of the creek the sandstone forms a natural outcrop for a distance of sixty feet. Other outcrops occur in neighboring valleys showing that it underlies at least a large part of the S. ½ of sec. 36, and part of the N. ½ of sec. 1.

The outcropping ledge has a thickness of about 36 to 40 inches at this point and is overlain by from 2 to 20 feet of a yellowish shale and surface soil and underlain by a bed of gray shale nine inches thick. Drill holes in the immediate vicinity are said to have penetrated from 120 to 181 feet of the sandstone occurring in thick beds separated by shale partings from two

[1]Hinds, Henry, and Greene, F. C., The stratigraphy of the Pennsylvanian series in Missouri; Missouri Bureau of Geology and Mines, vol. 13, 2d ser., p. 26, 1915.

Eldridge, Geo. H., The asphalt and bituminous rock deposits of the United States; Twenty-second Ann. Rept., U. S. Geol. Survey, pt. 1, pp. 259-261, 1901.

inches to fourteen inches thick. In the deepest drill hole the lower twenty feet did not show any bitumen in the sandstone.

The location of this deposit is such that it is very accessible, since it occurs where the wagon road crosses the creek and is only three-fourths of a mile from Higginsville at the junction of the Missouri Pacific and Chicago and Alton railroads.

The sandstone itself where not filled with bitumen is light gray in color and is micaceous, fine grained, and even-textured. The individual grains are mostly well rounded or subangular, and cemented together rather loosely, so that the rock is friable and easily cut with a pick. Where it is saturated with bitumen the color is dark brown to black, but exposed surfaces lose the bitumen, through evaporation, a fact which itself shows that the bituminous material contains but little asphaltine.

According to the owners, the following are the properties of the natural rock:

Properties of Higginsville natural asphalt.

Bitumen	7.4 per cent
Material passing 200 mesh screen	34.2 " "
80 " "	55.4 " "
40 " "	2.6 " "
10 " "	0.4 " "

Little has been done in the way of development of this deposit, although prior to 1900 some work was done near the Soldiers Home.[1] In the fall of 1917 a small quantity of the stone was taken out and used in paving a street in Higginsville, simply to test the worth of the material. The prospects of future development, however, are good, as the towns of Marshall and Warrensburg have investigated the paving at Higginsville and if it proves successful, may use the same material.

The paving done with this material consists of a street two blocks long and about 30 feet wide, put down in October, 1917. In preparing the street a foundation of concrete was made in the usual way and on top of this was put a two and one-half inch layer of asphalt prepared as follows:

Proportions of ingredients used in Higginsville pavement.

Natural bituminous sandstone	500 lbs.
Joplin "chat"	300 "
Sand	80 "
Limestone dust	60 "
Asphalt cement	60 "
Total	1000 "

[1]Eldridge, G. H., loc. cit.

The sandstone was pulverized and the whole mixed together at 300° F. and rolled down while hot. This forms a hard but resilient surface. So far it has successfully withstood traffic and extremes of temperature without showing much wear or cracking and flowing.

DEPOSITS NEAR SHELDON.

Asphaltic sandstone occurs in a large number of localities in Vernon County, but the commercial possibilities of the rock have been most investigated in the southeast part. These deposits occur chiefly about 4 miles east of Sheldon. Here the asphaltic rock outcrops along the sides of the bluffs and near the heads of the ravines and has been found by wells and test pits to persistently underlie a large area close to the surface. The exact size of the area underlain by the rock within a few feet of the surface cannot be definitely stated, though it is apparently to be estimated in terms of square miles. Buckley[1] stated it to be his belief that in this locality there is "an almost inexhaustible supply of bituminous or asphaltic sandstone of good quality."

Test holes and pits sunk in this locality show the following results: A well sunk in the SE. ¼ SW. ¼, sec. 27, T. 34 N., R. 30 W., encountered 21 feet of asphaltic sandstone at a depth of about 15 feet. In the SW. ¼ SW. ¼ of the same section asphaltic sandstone outcrops at several points near the heads of ravines. Two other test holes sunk in this section penetrated 16 and 11 feet of sandstone respectively at depths of 22 and 21 feet. Four test holes sunk in sec. 24, T. 34 N., R. 30 W., penetrated 30, 30, 26 and 30 feet, respectively, of asphaltic sandstone at depths of 5, 13, 9 and 11 feet. The exact sectional locations of the above holes are not known, but in the NE. ¼ SW. ¼ of this same section 27½ feet of asphaltic sandstone has been penetrated at a depth of 12 feet below the surface and the rock outcrops in a ravine near the test hole.

There is, thus, sufficient evidence that in this locality a very considerable area is underlain by 11 to 30 feet of asphaltic sandstone at depths of a foot or less to 25 feet below the surface. The overburden is chiefly residual clay easily removed.

The asphaltic sandstone in this locality occurs in the Cherokee shale. The rock is almost black on fresh fracture and

[1]E. R. Buckley, Biennial Report of the Missouri State Geologist to the Forty-third General Assembly, p. 22.

chocolate or dark brown colored in a weathered surface. It is micaceous and is very friable, apparently containing little or no cement other than the bitumen. The sand is composed of fine angular quartz grains of a light gray color when freed from the bituminous coating.

Two samples of the rock tested for the bituminous content have shown 7.5 and 8.2 per cent bitumen, though Buckley stated, referring to this locality, that the rock commonly contains 12 to 15 per cent asphaltic materials. From the samples observed, however, it is believed that the average of the rock will carry between 7 and 10 per cent bitumen.

GENERAL VALUE OF THE DEPOSITS.

It is reported that attempts to use the natural asphaltic sandstone, without additional asphalt cement, has proved to be a failure, both in Carthage[1] and in Springfield.[2] However, according to Muilenburg (see p. 187), when properly treated with additional asphalt cement, good roads can be made from the material. It will depend largely on local conditions whether it will be more economical to use the ordinary sheet asphalt artificial mixture, or to use the natural rock, properly treated.

TERTIARY SANDS AND GRAVELS.

Sand and gravel usually referred to the Tertiary has a widespread but scattering distribution in the State. It is best developed along Crowley's Ridge in the southeastern counties, but it also occurs widely in the Ozark region.

OZARK TERTIARY.

According to Winslow,[3] gravels consisting chiefly of carboniferous chert, lying on the hilltops adjacent to the streams and sometimes occupying terraces along the valley sides, occur in southwestern Missouri. The pebbles are subangular, waterworn and commonly yellow or brown in color. They are said to be abundant in western Jasper County, are reported along Spring River in Newton County, near the Osage in Henry, St. Clair and Benton counties, and along White River in Barry and Stone counties. Elsewhere in the State, as will be noted

[1]Buckley, E. R., Biennial Report of the State Geologist to the Forty-fifth General Assembly, p. 38, 1908.

[2]Shepard, E. M., Personal communication.

[3]Geological Survey of Missouri, vol. VII, pp. 425-426, 1894.

later, these gravels are capable of commercial exploitation. Not enough detail is available concerning their occurrence in the southwest area to make any very definite statement of their probable value, though it is likely that they may at least be used locally as road metal.

In Morgan County[1] a few isolated patches, referred provisionally to the Lafayette, are reported. They consist of subangular quartzite and chert pebbles, imbedded in red clay, and average about 1 inch in diameter. The only two exposures reported are near Versailles, where clay pits have been opened.

Buckley[2] reports that gravels, referred to the Lafayette, outcrop irregularly over much of the area of the southeast Disseminated Lead District. He does not give details of their distribution or lithologic character.

Along the Meramec, near Pacific, occurs the only area of the Ozark Tertiary that the writer had the opportunity to visit. This Tertiary is exposed in the gravel pit operated by the Pacific Cement Gravel Company located 1¼ miles south of Pacific, Franklin County, in sec. 13, T. 43 N., R. 2 E., closely adjacent to the right of way of the St. Louis and San Francisco Railroad Company, which line affords transportation for the output.

The gravel itself being covered with loess outcrops very sparingly, if at all, but it is exposed by the railway cut through a low terrace which rises about 20 feet above the present flood plain of Meramec River. The material consists of chert pebbles, varying from fine sand up to two inches and occasionally larger, the average being perhaps ¾ of an inch. Occasional sandstone pebbles and ferruginous, concretionary fragments are intermixed. The whole is firmly cemented by a very stiff, ferruginous red clay, so that it easily stands in vertical or overhanging walls in the pit (Pl. XXXIII, B). Cross bedding shows at places on the pit walls. The beds have been commonly referred to the Lafayette.

The presence of the gravel is reported to have been determined by auger bit over an area of about fifteen acres. The present pit is very irregular in shape, being about 400 feet wide by 600 feet long and varying from 5 to 25 feet in depth. The depth of the gravel below the bottom of the pit was reported not to be known. The overburden of from 5 to 12 feet of loess is removed chiefly by teams. The compacted loess is broken

[1]Marbut, C. F., Missouri Bureau of Geology and Mines, vol. 7, 2d series, p. 58, 1907.
[2]Missouri Bureau of Geology and Mines, vol. 9, pt. 1, 2d series, p. 68, 1908.

up by plowing and is handled with ordinary scrapers, though occasionally masses of it have been caved down. A considerable amount of this loess cover has been disposed of to the railroad for embankments.

A spur of the railroad runs into the pit. There is a trap over the track, and the gravel is handled with a scraper and dumped through the opening in the bridge of the trap into the cars. The scrapers were formerly operated by teams, but the difficulty of getting teams that would work on the trap caused the Company to install a donkey engine, and the scraper is operated by drum and cable (Plate I, A.)

The only preparation the material undergoes is the proper mixing of the more gravelly and more clayey portions. The capacity is a carload every two hours, and the entire output is used for surfacing roads and park walks. The material is marketed chiefly in St. Louis and St. Louis County.

COMMERCE SANDSTONE.

A prominent sandstone outcrops at or near Commerce in Scott County. The best exposures are in the cuts of the St. Louis and San Francisco Railroad, in and just north of Commerce. The rock is moderately fine-grained, buff to pink in color, and varies from a loose, friable sandstone to vitreous quartzite. The grains are well-rounded. About 20 to 30 feet of this formation are exposed in railroad cuts. Wilson[1] reports its extensive occurrence in the Benton Hills westward from Commerce. It has been referred to as Cretaceous[2] by some of the older writers, but Marbut[3] classifies it as a more indurated phase of the Tertiary. Similar sands and quartzites of Tertiary age, underlain by unconsolidated Tertiary clays, are reported from many parts of Crowley's Ridge in Arkansas.[4]

Portions of the formation are sufficiently friable, but are too impure to serve as the best grade of glass sand, though it would probably wash sufficiently clean. It is too fine for satisfactory structural sand, and would hardly be used for this purpose, especially as there is an abundance of good Tertiary sand and gravel in the vicinity. It probably has no economic value. Herewith follows a description of this sand.

---

[1]Wilson, M. E., Personal communication.

[2]Swallow, G. C., Gazeteer of Missouri, pp. 760-761, 1874.

[3]The evolution of the northern part of the lowlands of southeast Missouri; University of Missouri Studies, vol. 1, No. 3, pp. 24-25.

[4]Call, R. E., Geology of Crowley's Ridge, Arkansas Geological Survey, Ann. Rept., vol. 2, pp. 90-102.

Sample 146.—This sample was taken from the railroad cut in the north edge of Commerce. It is of a reddish to pinkish tint and for the most part very friable, though at places it grades into vitreous quartzite. It consists almost wholly of moderately-rounded quartz grains. Ninety-eight per cent passes the 30-mesh, and only 48 per cent is retained on the 60-mesh sieve. It has an effective size of 0.16 mm. and a uniformity coefficient of 1.49, in these respects coming close to the average St. Peter sand. It has a sp. gr. of 2.636, 48 per cent voids, and weighs 85.5 lb. per cu. ft., or 2308 lb. per cu. yd. It shows 0.20 per cent dirt and washes nearly white.

In the table on p. 126 are given the results of the screen tests, and the following is a chemical analysis of this sample:

Analysis of Commerce sandstone.

SiO_2	99.50
Al_2O_3	0.24
Fe_2O_3	0.12
CaO	Trace
MgO	Trace
Ignition loss	0.14
	100.00

CROWLEY'S RIDGE SANDS AND GRAVELS.

Along the lowland of southeast Missouri, particularly in Scott, New Madrid, Stoddard and Dunklin counties, are extensive deposits of gravel and sand which have always been considered of Tertiary age. The gravel occurs in the form of low, rolling hills which rise from ten or fifteen to possibly a hundred feet or more above the present bottoms. The material varies much from place to place in composition, coarseness, angularity, color, and depth.

In general it consists of interbedded sands, gravels, and clays. The gravels are very pockety in distribution, the constituent pebbles being almost entirely chert and quartz. Occasionally indurated sandstone pebbles, as well as sandy ferruginous concretions were noted. The cherts range in color from almost white through various shades of red, brown, and yellow to dull black. In size, the grains vary from minute particles to 3 inches or more in diameter, though pebbles above 2 inches are the exception. The coarser particles are subangular to well-rounded, the finer sand subangular to sharp. It is reported that the chert frag-

ments in places carry Mississippian fossils.[1] The material is very pockety in its distribution, varying in very short distances from coarse gravel through finer sand into clay.

SCOTT COUNTY.

Ellis Pits.—About two miles southwest of Commerce in Scott County, on the property of Mr. Joe Ellis, several small pits have been opened up in this material. In the SE. ¼ NE. ¼ sec. 26, T. 29 N., R. 14 E., considerable sand has been taken from two or three small pits. Two grades of sand were sampled, and a brief description of each follows:

Sample 141.—This is a medium-grained sand, poorly rounded and with many sharply angular grains. The color is slightly reddish from iron stain. Quartz and chert are present, the former being the most abundant. The sp. gr. is 2.61, voids 46 per cent, weight, dry and loose, 88.25 lb. per cubic foot, or 2383 lb. per cu. yd. Washing entirely removes the red discoloration and shows a removable dirt content of 5.3 per cent. The effective size is 0.2 mm. and the uniformity coefficient is 2.20. On p. 206 are given the results of screen tests of the sand. All the sand passes the 10-mesh, and 86 per cent is retained on the 60-mesh sieve. This sand seems to occur in a rather extensive pocket, but gives way in a few rods to material like sample 142. There is practically no overburden. The sand is used locally for plastering and brick work.

Sample 142.—This sample is from the same locality but is a much coarser sand, most of the grains being subangular to moderately sharp. It contains occasional pebbles up to a half inch in diameter. The larger pebbles are all chert, but the finer grains show chert and quartz in nearly equal proportions. The sample shows very little ferruginous discoloration. The sp. gr. is 2.63, voids 33 per cent, weight, dry and loose, 108.9 lb. per cubic foot, or 2935 lb. per yard. Washing shows a removable dirt content of only 0.6 per cent. The effective size is 1.05 mm. and the uniformity coefficient 1.60. About 46 per cent is retained on the 10-mesh and 94 per cent on the 20-mesh screen. It is thus seen to be a coarse sand with only a small per cent of fines. The sieve tests are given on p. 206. The pit has not been opened up, and it is impossible to say how abundant this phase may be. As in the former pit, there is only a slight overburden. This sand is used locally for concrete.

[1] Wilson, M. E., Personal communication.

A somewhat coarser concrete gravel was sampled from the same locality, and the description of the material follows:

Sample 229.—Of this sample only 33 per cent is retained on the ¼-inch screen. Of the remaining 67 per cent of screenings 38.4 per cent is retained on the 10-mesh, and about 95 per cent on the 60-mesh sieve. The plus 20-mesh product is almost wholly chert, the finer material largely quartz. The sp. gr. of the minus ¼-inch product is 2.62, voids 35 per cent, and the weight 106 lb. per cu. ft., or 2862 lb. per cu. yd. The effective size is 0.32 mm. and the uniformity coefficient 5.2. Washing removed 10 per cent dirt from the minus ¼-inch material. The screen tests are given on page 206.

In the SW. ¼ NW. ¼ of sec. 25, T. 49 N., R. 14 E., also on the Ellis property, is located a more extensive pit from which gravel has been taken for road dressing (Pl. XXXIV, A). The material consists of a flint gravel which contains pebbles up to 3 inches in diameter. These, however, average much lower, possibly less than an inch. Reddish-brown and yellow flints predominate, but white, gray, and dull black pebbles were noted. The gravel is strongly cross-bedded and very pockety, grading out in short distances into coarse sand or stiff ferruginous clay. The material is sufficiently indurated to stand in the pit in vertical or overhanging walls. Sample 143 which represents the coarse sand from this pit is used extensively as the top coat for roads, and is said to prove very satisfactory, as it cements well and furnishes a hard wearing surface. It closely resembles the so-called Lafayette gravels.

Sample 143.—This sand is coarse and highly ferruginous. The grains are a mixture of quartz and flint and are subangular to sharp. The sp. gr. is 2.61, voids 46.1 per cent, weight per cubic foot 87.92 lb., or 2374 per cu. yd. The effective size is 0.20 mm. and the uniformity coefficient 5.65. The sand washes nearly white, the removable dirt content being 10.6 per cent. About 97 per cent passes the 10-mesh and nearly 90 per cent is retained on the 60-mesh sieve. The screen test is given on p. 206.

The following samples were collected from the property of Mr. Ellis, and shipped to the Bureau of Standards, Washington, D. C., where tests were made on concrete produced from the sand and gravel.

Sample A. About 500 pounds. A red gravel of flint pebbles, with red, ferruginous, sandy clay matrix. This material is used locally for road metal.

A. Joe Ellis gravel pit, Commerce, Scott County. Tertiary (so-called Lafayette) red gravel used for road metal.

B. Glassstetler pit, Benton, Scott County. Tertiary (so-called Lafayette) red gravel used for road metal. Note the loess overburden.

Sample B. About 1500 pounds. Moderately fine gravel, with sandy matrix, used locally for concrete.

Sample C. About 150 pounds. A coarse gravel, with less fine material than "B." Used to some extent locally on roads.

Sample D. About 500 pounds. A moderately fine sand used locally for plastering and bricklaying.

Following is the report made by the Bureau of Standards, on the material submitted:

Report of tests on concrete aggregate from Commerce, Mo.

"The tests reported herein are made on samples of sands and pit run gravels taken from the Scott County Hills, otherwise known as the Benton or Commerce Hills near Commerce, Missouri, by a representative of the Bureau of Geology and Mines of Rolla, Missouri."

Physical tests of Portland Cement used.

Lab. No.	Specific gravity.	Fineness, Per cent passing mesh.		Soundness.			Time of setting.	
				28 days.		Steam.	Initial H M	Final H M
		100	200	Air.	Water.	5 hrs.		
10118	3.22	95.2	78.6	OK	OK	OK	4 20	8 05

Tensile Strength.

	Water.	7 days.			28 days.		
Neat	22.0%	601	644	586	900	824	704
1:3 Std. Sand	10.2%	232	238	259	284	317	308

Chemical Tests.

MgO.....2.16	SO_3.....1.59	Loss.....1.71	Insol. Residue.....0.14

Other Properties of Aggregates.

	Weight, cu. ft.	Specific gravity.	Per cent voids computed.
Pit run gravel B	121	2.58	24.35
Pit run gravel C	105	2.41	30.40
Gravel B with all material below ¼-inch screened out	104	2.58	35.40
Gravel C with all material below ¼-inch screened out	99	2.53	37.30
Sand from gravel B (all below ¼-inch)	114	2.62	30.30
Sand from gravel C (all below ¼-inch)	91.2	2.50	41.50
Sand D	92.8	2.64	43.80

Mechanical Analysis [of Gravel and Sand].

Marked gravel.	Character of material.	Per cent passing screens—openings, inches.					
		2	1½	1	¾	½	¼
B.....	Pit run gravel.....	100	100	98.87	97.75	96.25	80.5
C.....	Pit run gravel.....	94.25	83.44	65.44	58.75	51.25	37.79

Sand.	Sieves No.—Per cent passing.										
	4	6	8	10	14	20	28	35	48	65	100
D*.....	100	100	100	99.6	99.3	98.8	96.6	66.7	16.5	6.00	1.84
Sand from B[1].	93.6	86.3	74.2	54.8	44.8	39.9	36.6	31.9	22.2	13.1	5.8
Sand from C[1].	89.3	78.7	72.8	67.8	63.9	58.1	49.5	35.3	19.2	14.6	11.2

Note—(*) Sand submitted.
(1) All less than ¼ inch.

Mortar Strength Tests.

(1 part cement—three parts sand.)

Sand.	Age, days.	Water.	Tensile strength. (Lbs. per square inch.)				Compressive strength. (Lbs. per square inch.)			
						Average.				Average.
From Gravel B, all below ¼-inch	7	10.0%	340	360	370	357	2562	2750	2790	2667
	28		435	455	425	438	4620	5010	4965	4865
	90		381	400	437	406	6000	5930	6050	5993
From Gravel C all below ¼-inch	7		123	120	115	119	946	837	862	876
	28	18.5%	218	160	197	192	1762	1600	1762	1710
	*									
D	7	13.0%	215	215	220	217	985	940	900	942
	28		310	272	285	289	1750	1900	2000	1883
	90		366	322	374	354	2500	2375	2275	2383
Ottawa Standard Sand	7	10.2%	187	155	148	163	1162	1137	1100	1133
	28		321	267	318	302	2125	2025	2140	2097
	90		467	505	465	406	2780	2750	3040	2857

Note—(*) Insufficient material for 90-day tests.

Compressive Strength of Concretes.

(6x12-inch cylinders—quaking consistency—stored in damp closet.)

Constituents of concrete.	Per cent water.	Age days.	Maximum load.	Compressive strength, lbs. per sq. in.
1 part cement, 4 parts pit run gravel B.....	8.7	7	48,750 48,250	1712
		28	59,300 65,250	2200
		90	88,700 74,650	2870
1 part cement, 6 parts pit run gravel B.....	8.6	7	26,000 27,500	946
		28	33,000 41,500	1322
		90	43,900 38,200	1450
1 part cement, 8 parts pit run gravel B.....	8.8	7	14,100	496
		28	24,500 20,100	788
1 part cement, 2 parts sand screened from gravel B (all below ¼-inch), 4 parts gravel B with material below ¼-inch screened out.....	8.4	7	37,500 30,300	1193
		28	47,600 54,200	1798
		90	78,000 66,000	2550
1 part cement, 2 parts sand screened from Gravel C (all below ¼-inch), 4 parts gravel C with material below ¼-inch screened out.....	11.0	7	16,850 18,800	642
		28	21,800 19,720	734

"Conclusions:

"Pit run gravel B although it contains a large excess of material below ¼-inch in size yields a concrete of good strength in proportion of 1 part Portland cement to 4 parts pit run gravel B. Comparing the tests of concrete containing cement and pit run gravel as received with tests made on a concrete mixture of 1 part cement, 2 parts sand (material below ¼-inch screened rom gravel B) 4 parts gravel B with material below ¼-inch screened out it would seem that about the same strength can be obtained with a mixture of 1 part cement to 5 parts pit run gravel B as is obtained by separating this pit run gravel into sand and gravel by a ¼-inch screen and recombining in the proportion of 1:2:4. However it is not safe to recommend the use of pit run materials as there is bound to be more or less variation in gradation which may materially affect the quality of the concrete and at the present time few engineers will accept pit run material. Unless there are other avail-

able sources of supply of large aggregates such as gravel or crushed stone the presence of the large excess of sand in pit run gravel B would probably make the working of this pit, for general concrete work uneconomical unless there is no other source of supply near at hand. If the trade will accept material screened on the No. 8 in place of ¼-inch a greater proportion of so-called gravel would be obtained which would make the operation of the pit more profitable.

"The sand composed of material passing the ¼-inch screen from pit run gravel B yields a mortar of excellent strength indicating that it is a good sand for concrete work.

"The physical tests of pit run gravel C show that it contains a large excess of clay which results in a comparatively low strength when separated into sand and gravel and incorporated into a 1:2:4 concrete. This material was separated into sand and gravel by the ¼-inch screen. The mortar tests of sand from pit run gravel C show comparatively low values for both tensile and comparative strength. This material would probably be improved by washing before using. There was insufficient material to determine whether pit run gravel B could be improved by mixing with it gravel C which would increase the proportion of coarse aggregate present.

"The physical tests including the mortar strength tests of sand D show that this sand would be satisfactory for plastering and masonry work."

The pits described above are between a mile and a half and two miles from Commerce, and all material is hauled with teams. The topography favors the building of a spur across the flood plain from Commerce to the foot of the gravel ridge. Shallow wells at the edge of the plain would probably supply ample water. Stripping is light and easily handled with team and scraper. The sand as now marketed is neither washed nor screened at the pits.

At present little material is shipped, but the sand and gravel is used extensively for local road improvement and building purposes. This is one of the best bank sands observed in the State and is probably capable of extensive exploitation. Before installing a plant, care should be used in locating favorable places, and in making auger-bit tests of the extent and depth of deposits. By proper washing and screening, these beds would probably yield one of the best structural sands to be had in Missouri.

Along the hillside on which these pits are situated but much nearer town, are exposed along fresh road-cuts and gullies several thin beds of a very peculiar character, which upon inspection appear to be an extremely fine sand, that occurs in layers 2 to 8 inches thick, and may be traced several yards laterally. The sand comes out in thin layers but is easily crushed down in the fingers. The parting planes of these layers are spangled with fine flakes of some micaceous-appearing mineral.

Analysis of the material yields the following results (Sample No. 145.)

Analysis of fine sand from Commerce.

SiO_2	88.52
Al_2O_3	7.60
Fe_2O_3	0.78
CaO	0.06
MgO	trace
Ignition loss	2.84
	99.80

On page 206 is also given the screen test of a sample of the same sand.

Sample No. 145.—Over 89 per cent passes the 200-mesh screen. It has a sp. gr. of 2.63 or higher. As the picnometer was placed under the air pump and all bubbles carefully exhausted out of the material, the figure given is probably very close to right. Dry and loose, it has 58.8 per cent voids, weighs 67.72 lb. to the cu. ft. and about 1828 lb. per cu. yd.

The material if obtainable in sufficient quantity might have value for polishing powders or scouring soaps.

Benton Pit.—Near Benton in Scott County, along the hills variously known as the Benton, Commerce, and Scott County Hills, which constitute the northern end of Crowley's Ridge, are numerous other occurrences of gravel. In a few places there has been commercial exploitation of this material. Scott County owns a pit in the SW. ¼ sec. 32, T. 29 N., R. 14 E., about two miles northeast of the village of Benton. The material is used wholly for road purposes. Stripping averages from 5 to 15 feet of loess.

Sample 232.—This sample comes from the pit described above and is a flint gravel with a clay matrix. The pebbles have a maximum size of about 2½ to 3 inches. Seventy-three per cent of the sample is retained on the ¼-inch screen. Of the portion which passed the ¼-inch, 41 per cent was retained on the 10-mesh and 78 per cent on the 60-mesh sieve. The sp. gr. is 2.57, the voids 33 per cent and the weight per cu. ft. 107.6 lb., or 2907 lb. per cu. yd. The effective size is less than 0.1 mm. and the uniformity coefficient above 12.00. The low effective size and high uniformity coefficient are caused by the high content of the clay, which shows in the 14 per cent of minus-200-mesh product. Washing removed 24 per cent of dirt, chiefly clay. This dirt content shows a higher percentage

than the total minus 100-mesh product, partly because there were clay lumps which remained with plus 10-mesh product on screening but which washed out, and partly because the pebbles carried a coating of clay which could not be detected by screening but which washed out completely. The dirt test was made on the minus ¼-inch product. Screen tests are tabulated on p. 206.

Glassstetler pit.—At the fork of the Benton-Hamburg and the Benton-Oran roads, on the Glassstetler place in the NW. ¼ SE. ¼ sec. 11, T. 28 N., R. 13 E., and near Benton, there is an extensive pit of very ferruginous gravel similar to that described as sample 143 (Pl. XXXIV, B), and also referred to the Lafayette. The material is used for street and road work in Benton and vicinity. Herewith follows a description of a sample from this pit.

Sample 233.—Fifty-three per cent of this sample is retained on the ¼-inch screen. The plus ¼-inch product is wholly flint, and contains many pebbles up to 1½ inches in diameter. Of the remaining 47 per cent of screenings, 22 per cent is retained on the 10-mesh and 91 per cent on the 60-mesh sieve. The minus 20-mesh product is largely quartz sand, subangular to sharp. The sp. gr. is 2.61, the voids 41 per cent, and the weight 96.2 lb. per cu. ft., or 2597 lb. per cu. yd. The effective size is 0.25 mm. and the uniformity coefficient 2.92. Washing removed about 7 per cent dirt, largely a very ferruginous clay which forms an excellent cementing material, causing the gravel to bind well. The washing test on this sample was made on the total, including both plus and minus ¼-inch product. The screen tests on this gravel are given in the table on page 206.

STODDARD COUNTY.

Williams pit.—On the property of M. J. Williams in the SW. ¼ SW. ¼ sec. 17, T. 24 N., R. 10 E., is a gravel pit, the output of which is sold chiefly in Bernie, Stoddard County. The gravel is not washed or screened, is handled without machinery, and hauled by teams a distance of 5 to 6 miles. The cleaner material is used for concrete, the more clayey for road building. There is no overburden. Similar gravel is exposed at several points in the vicinity. A description of a sample follows.

Sample 235.—Of this material, 79 per cent is retained on the ¼-inch screen. This coarse product is wholly flint and contains pebbles up to 3 inches or more in diameter. Of the minus ¼-inch product, 29 per cent is retained on the 10-mesh and 76

per cent on the 60-mesh sieve. The minus 100-mesh product makes up 19 per cent of the screenings. The sp. gr. is 2.60, the voids 34 per cent, and the weight per cu. ft. 107.2 lb., or 2894 lb. per cu. yd. The screenings washed 29 per cent dirt. The effective size is 0.10 mm. and the uniformity coefficient 12.30. The low effective size and high coefficient are due to excessive clay fines. (See p. 206 for screen tests.)

A road cut near the south quarter corner of sec. 25, T. 25 N., R. 9 E., in Stoddard County exposes gravel in quantity. No pits have been opened, but the material seems to be similar to that just described.

Dexter pits.—Near the south quarter corner sec. 11, T. 25 N., R. 10 E., about a mile north of Dexter in Stoddard County, along the Dexter-Bloomfield road, are several gravel pits owned by the city of Dexter. The loess overburden is light. The gravel consists of flint pebbles up to 2 inches in diameter in a highly ferruginous matrix of clay and sand. The material binds well and is used wholly for street and road work. It is very similar to the material (samples 143 and 233) from the road-gravel pits at Commerce and Benton, which have been referred to the Lafayette. The description of a sample follows.

Sample 239.—Of this sample 53 per cent is retained on the ¼-inch screen. Of the finer product, 15 per cent is retained on the 10-mesh and 96 per cent on the 60-mesh screen. The sp. gr. is 2.62, the voids 39 per cent, and the weight 99.8 lb. per cu. ft., or 2695 lb. per cu. yd. The effective size is 0.32 mm. and the uniformity coefficient 1.87. Washing removes 15½ per cent dirt from the minus ¼-inch product. This dirt is largely highly ferruginous clay and does not show in the fines because it adheres to the grains. Screening shows only about 2 per cent of minus 100-mesh product. (See table on p. 206, for screen tests.)

DUNKLIN COUNTY.

Across the W. ½ sec. 35, T. 23 N., R. 9 E., in Dunklin county are numerous exposures of good coarse gravel. In this vicinity, Crowley's Ridge is very narrow and sharply dissected on both sides, and the steeply heading ravines expose gravel slopes on both sides of the road which follows the main ridge. A few small pits have been opened but are neglected. The ridge in this section shows more gravel than was seen at any other point, and if the area had suitable transportation, it could furnish gravel to a large surrounding region. Fresh sections

were not exposed, and it was therefore impossible to determine the depth of the gravel. No doubt it is considerable, although that on the lower slope of the ridge may be in part wash and landslide material from higher up. Farther south, the ridge becomes much lower and less dissected, and no more exposures of gravels were seen for several miles.

Wetherholt pit.—About a mile and a half north from Campbell, Dunklin County, in the NW. ¼ NW. ¼ sec. 34, T. 22 N., R. 9 E., a large gravel pit is operated by G. W. Wetherholt. There is an overburden of 5 to 15 feet of loess. The pebbles are flint in a matrix of sand and some clay. The cleaner product goes to Campbell for concrete work, the most clayey is used for road metal. The following sample was taken from this pit:

Sample 236.—This sample represents the cleaner gravel. About 63 per cent is retained on the ¼-inch screen and consists of pebbles up to 1½ inches in diameter. Of the minus ¼-inch product, 38 per cent is retained on the 10-mesh, and 94 per cent on the 60-mesh sieve. The sp. gr. is 2.61, the voids 35 per cent and the weight 106.2 lb. per cu. ft., or 2867 lb. per cu.yd. The effective size is 0.28 mm. and the uniformity coefficient 5.70. Washing removed 6 per cent of dirt from the screenings. (See table, p. 206, for complete screen tests.)

Dalton pit.—About 3 miles west of Campbell in Dunklin County, in the NE. ¼ sec. 6, T. 21 N., R. 9 E., Mr. M. A. Dalton operates a gravel pit. There is about 2 feet of loess overburden, and the exposure covers 20 acres or more. The pebbles are flint in a sandy clay matrix. The cleaner product goes to Campbell for concrete aggregate, the clayey portions are used locally for road metal. A sample follows.

Sample 238.—Of this sample about 68 per cent is retained on the ¼-inch screen. The largest pebbles run about 1 inch. Of the minus ¼-inch product, 36 per cent is retained on the 10-mesh, and 84 per cent on the 60-mesh. The sp. gr. is 2.62, the voids 32 per cent, and the weight 111.3 lb. per cu. ft., or 3005 lb. per cu. yd. Washing removes 11 per cent dirt from the screenings. The effective size is 0.19 mm. and the uniformity coefficient 6.50. The result of screen tests is given on p. 206.

VALUE OF CROWLEY'S RIDGE GRAVELS.

The highly ferruginous gravels described above make an excellent road metal. The clayey gravels are also used for

road dressing. The Tertiary gravel is usually rather dirty for the best structural material, but with proper washing and screening these beds would yield an inexhaustible quantity of good sand and gravel suited for all structural purposes.

A hasty survey of the ridge made by the writer revealed a large number of places where the gravels occur in quantity to be of value, but no doubt many others equally favorable were overlooked.

PLEISTOCENE SANDS AND GRAVELS.

The statement that Missouri River forms the southern boundary of the glaciated area in this State is in general true, but there is evidence that the ice reached farther south, in the vicinity of St. Louis and probably in numerous places farther west. The writer also saw igneous pebbles, said to have been picked up in an open field, near Longtown in Perry County. No igneous rock outcrops are known in the County, and the material may be of glacial origin.

It is true, however, that glacial deposits of economic value probably do not occur south of Missouri River, except possibly certain deposits in St. Louis and vicinity. These will be described later.

GLACIO-FLUVIAL DEPOSITS.

Economically the most important glacial gravels known in the State occur in the northwest counties, particularly in Nodaway.

NODAWAY COUNTY.

These deposits constitute extensive glacio-fluvial beds, either a broad outwash apron, or a deposit of worked-over glacial material laid down during the interglacial times. It has been suggested by Mr. F. C. Greene of this Bureau, that the material may be of Aftonian age. These glacio-fluvial deposits are overlain by typical till, a few inches to 100 feet thick. This till caps most of the divides, and the stratified gravels occupy the slopes of the valley sides.

The bowlder clay overburden carries pebbles and occasional large bowlders of granite, trap, quartzite and chert. The glacio-fluvial gravels are strongly cross-bedded and very pockety in character, the various lenses thickening and thinning rapidly and irregularly and containing many "horses" of clay. The

gravels carry occasional pebbles up to 3 or 4 inches in diameter, but average less than 2 inches. The material consists largely of limestone and flint fragments from the local formations, but there is a notable percentage of foreign pebbles among which granite, trap, and quartzite are the most conspicuous. Many of the pebbles, particularly the granites, are badly decayed, and it is believed this would prevent the use of these gravels in the highest class of work where great strength was required.

The matrix varies from coarse sand to fine clay, but in the deposits clay is a conspicuous constituent, and coats most of the pebbles with a thin film.

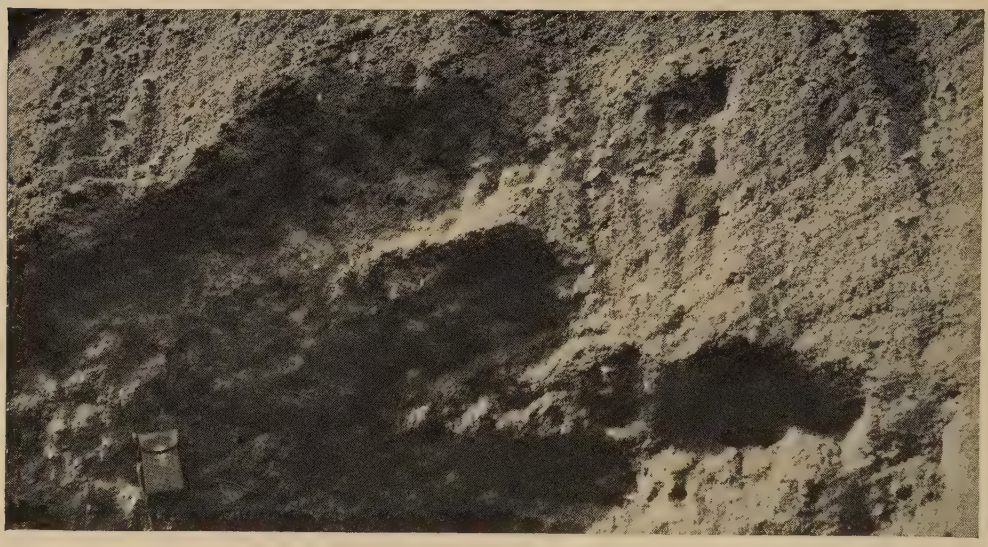
Along the east side of the valley of One Hundred and Two Creek for several miles both north and south of Maryville in Nodaway County, extends a line of bluffs facing westward. The top of this ridge is capped with bowlder clay, but along the sides, wherever trenched by erosion, the bowlder clay is seen to rest on these stratified gravels. These are typically exposed in a number of pits.

De Armand pit.—This pit is located on part of the old L. T. Lee estate, is 3½ miles northeast of Maryville, and is the largest pit in the County. The till overburden, which varies from 3 to 12 feet and averages about 6 feet, is first plowed and then stripped back with team and scraper (Pl. XXXV, A). The present excavation is about 150 feet wide and 300 feet long, and varies from 10 to 50 feet in depth. The contact between the gravel and the overlying till being a very uneven one, the thickness of the overburden varies with the inequalities of its lower as well as of its upper surface. A clay "horse" was encountered on one side of the pit, rising above the floor and thickening rapidly into the bank. Near the base of the pit, water was encountered, which trickles out slowly but not in quantities to interfere with the work.

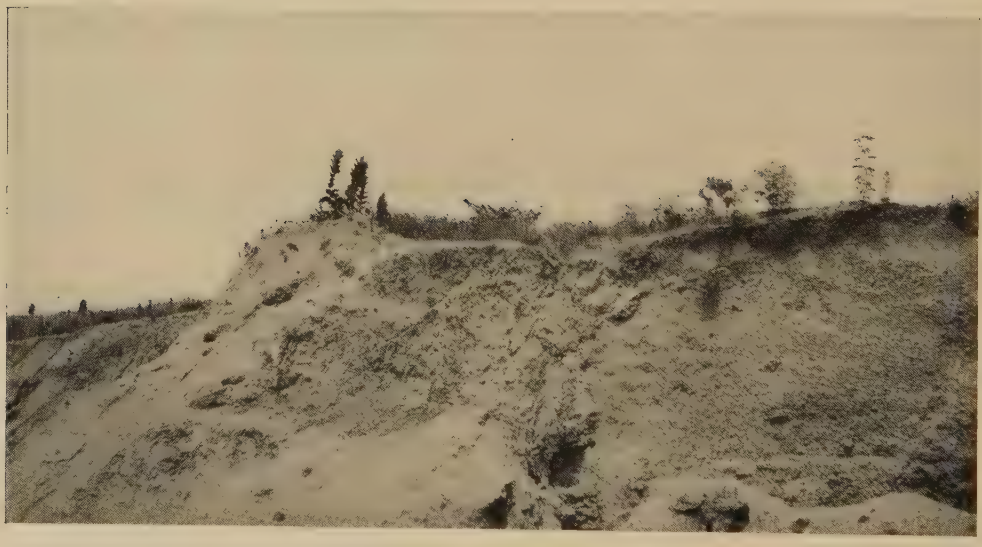
The gravel is loaded by hand and hauled to town with teams (Pl. XXXV, B). Two trips a day are regularly made by each team and about a yard and a half is hauled at a load. Gravel sells for 50 cents per yard at the bank and for $1.75 in Maryville. This pit produces about 3000 yards per year. The gravel is neither washed nor screened for the market. So far as could be ascertained, it is not washed at all for use and is not screened for concrete work, but it must, of course, be sifted for brick work, plastering, etc. No gravel is shipped, the entire output being used in Maryville and vicinity, largely for road metal and con-

A. De Armand pit, Maryville, Nodaway County. Stripping till overburden from so-called Aftonian gravel.

B. Glacio-fluvial (Aftonian?) gravel at the De Armand pit, Maryville, Nodaway County.



A. Cross bedding in glacio-fluvial (Aftonian?) gravels. De Armand pit, Maryville, Nodaway County.



B. The Jake Thompson pit, Guilford, Nodaway County. Shows channel in Aftonian(?) gravel, filled with clay.

crete work, but occasionally for plastering and brick work. Plates XXXV, B and XXXVI, A show the overburden and the cross bedding in this pit. Herewith is given a description of a typical sample.

Sample 173.—This sample from S. J. De Armand's pit consists of a typical glacial gravel, with pebbles up to 2 inches in diameter. The pebbles are chiefly chert and limestones, with a few fragments of quartzite, granite, and other foreign material. The matrix is finer sand and clay, which effervesces freely in cold dilute hydrochloric acid, indicating the presence of finely pulverized limestone. Seventy-seven per cent of the gravel passes the ¼-inch screen. Of these screenings, over 46 per cent are retained on the 10-mesh and over 96 per cent on the 60-mesh screen. The effective size is 0.5 mm., the uniformity coefficient between 3.60 and 4.60, sp. gr. 2.60, voids 44 per cent, weight per cu. ft. 91.3 lb., and per cu yd. 2460 lb. The gravel washes 5.00 per cent dirt. Washing removes the film of clay on the pebbles and leaves the sand in good shape. Screen tests are tabulated on p. 206.

Stark, C. N.—This pit is located about 3½ miles southeast of Maryville in Nodaway County along the same line of hills on which Mr. De Armand's pit is being operated. The bowlder clay overburden is about 5 to 6 feet, and the layer of gravel 7 to 12 feet thick. The pit is about 100 by 200 feet. Mr. Stark has recently opened a new pit, from which he strips about 2 feet of clay and uncovers about 10 to 12 feet of gravel. The output is all marketed at Maryville and vicinity for roads and structural purposes. The material is in all respects similar to that from other pits in the region.

Thornhill, Will.—Mr. Thornhill has been operating on the property formerly owned by Jas. Hook, about 1½ miles east of Maryville. The bowlder clay overburden has become so thick at this location that he reports work practically abandoned.

Mozingo, J. S.—For some time, Mr. Mozingo operated a pit just across the road from Mr. Thornhill. He also reports work as practically abandoned on account of the increasing depth of the overburden.

Heitman, Henry.—Mr. Heitman has a small pit about 4½ miles southeast of Maryville, on the same line of gravel hills mentioned above. There is about 2 feet of clay cover which he keeps stripped back. Gravel is sold at the pit, but he does not deliver. Like other pits in this vicinity, when the owner

keeps the pit open and properly stripped, gravel is sold at 50 cents per yard.

Mr. Heitman also has a small sand pit on his farm, but he is doing nothing with it at present. It was not sufficiently opened up for the writer to get a fair idea of the extent of the sand or of the depth of the overburden. A sample of the sand was tested with the following results:

Sample 175.—This is a fine-grained glacial sand in which grains of chert, limestone, quartz, feldspar and various igneous rocks could be detected. The grains are much coated with clay. The material all passes the 10-mesh, and 95 per cent is retained on the 60-mesh screen. The effective size is 0.36 mm. and the uniformity coefficient 1.82. Washing shows 6 per cent dirt, but completely removes the films from the individual grains and leaves them in good condition. The complete screen test is given in the table, p. 206.

Hasty, J. M.—Mr. Hasty is opening up a similar pit about a mile east of town. He keeps the pit stripped and in good condition, and sells at the bank for 50 cents per yard. At present he is taking off about 2 feet of clay. A rather thorough testing over the hillside has shown a large body of gravel, with from one to three feet of cover.

Thompson, J.—Mr. Thompson has a pit much like those just described. It is located on the east side of Platte River valley, and a mile north of Guilford, Nodaway County (Pl. XXXVI, B).

The working face is about 100 feet long and from 8 to 20 feet high, with a bowlder clay overburden of from 1½ to 2 feet. Stripping is done with team and scraper, and gravel is sold at the pit for $1.00 per yard. The output is all used locally for roads and concrete work. The material is very similar to that from De Armand's pit near Maryville, and is similarly situated. The gravel in this pit is strongly cross bedded (Pl. XXXVII). A detailed description of the sample is appended.

Sample 176.—About 67 per cent of the sample passes the ¼-inch screen. Of these screenings, 47 per cent is retained on the 10-mesh and 93 per cent on the 60-mesh sieve. The effective size is 0.38 mm., the uniformity coefficient between 5.13 and 8.94, and the sp. gr. is 2.60. The percentage of voids is 36.6. The sand weighs 103 lb. per cu. ft., or 2781 lb. per cu. yd. Washing removes 5.9 per cent dirt and leaves the individual grains entirely free of the clay film present in the unwashed sample. For a summary of the screen tests, see table on p. 206.

SCREEN TESTS ON TERTI

No.	Passing each sieve and retained on the next.												Retained on No. 10	Total passing each si						
	200	150	100	90	80	70	60	50	40	30	20	10		200	150	100	90	80	70	60
141	0.81	0.19	4.21	0.45	1.00	2.47	3.90	15.80	15.92	40.55	10.11	4.50	0.09	0.81	1.00	5.21	5.66	6.66	9.13	13.03
142	0.00	0.00	0.14	0.09	0.06	0.22	0.28	0.93	1.14	1.09	1.90	47.18	46.97	0.00	0.00	0.14	0.23	0.29	0.51	0.79
143	1.51	0.45	2.26	1.76	0.75	2.58	1.46	3.99	4.62	9.68	14.61	54.17	2.16	1.51	1.96	4.22	5.98	6.73	9.31	10.77
145	89.38	0.66	7.74	0.25	0.08	0.16	0.16	0.25	0.41	0.33	0.17	0.41	0.00	89.38	90.04	97.78	98.03	98.11	98.27	98.43
146	0.00	0.09	1.67	7.35	3.94	17.70	21.24	25.69	13.28	7.11	1.93	—	—	0.00	0.09	1.76	9.11	13.05	30.75	51.99
229	0.50	0.10	1.50	0.10	0.40	0.50	1.60	3.60	14.90	13.70	5.30	19.40	38.40	0.50	0.60	2.10	2.20	2.60	3.10	4.70
232	14.00	1.20	2.80	0.10	0.90	1.00	1.60	2.90	3.70	6.40	5.30	18.50	41.40	14.00	15.20	18.00	18.10	19.00	20.00	21.60
233	1.90	0.25	2.70	0.15	0.70	0.90	2.20	4.30	14.40	24.40	16.40	9.50	22.20	1.90	2.15	4.85	5.00	5.70	6.60	8.80
235	5.50	0.30	13.10	0.60	1.00	1.70	1.70	3.20	3.00	6.40	10.20	23.40	29.40	5.50	5.80	18.90	19.50	20.50	22.20	23.90
236	1.30	0.20	1.10	0.20	0.50	1.00	1.10	4.50	5.20	15.20	11.40	19.90	38.40	1.30	1.50	2.60	2.80	3.30	4.30	5.40
238	1.00	0.20	6.20	0.40	1.30	2.80	4.50	3.20	7.60	10.40	12.30	13.30	36.00	1.00	1.20	7.40	7.80	9.10	11.90	16.40
239	0.60	0.10	1.10	0.10	0.30	0.50	0.90	4.00	8.30	36.40	22.60	10.10	15.00	0.60	0.70	1.80	1.90	2.20	2.70	3.60

SCREEN TESTS ON GLAC

No.	Passing each sieve and retained on the next.												Retained on No. 10	Total passing each						
	200	150	100	90	80	70	60	50	40	30	20	10		200	150	100	90	80	70	60
173	1.45	0.20	0.93	0.04	0.10	0.41	0.41	1.45	1.45	4.15	9.75	33.00	46.70	1.45	1.65	2.58	2.62	2.72	3.13	3.54
175	2.45	0.29	0.56	0.30	0.15	0.30	0.50	1.50	5.30	21.90	47.60	19.05	———	2.45	2.70	3.30	3.60	3.75	4.05	4.55
176	4.32	0.20	1.11	0.12	0.12	0.62	0.54	1.21	1.91	9.00	14.25	18.80	47.80	4.32	4.52	5.63	5.75	5.87	6.49	7.03
207	0.27	0.04	0.39	0.04	0.12	0.16	0.43	1.22	2.76	11.84	29.48	40.60	12.72	0.27	0.31	0.70	0.74	0.86	1.02	1.45

RY SANDS AND GRAVELS.

e.					Effective size.	Uniformity coefficient.	Specific gravity.	Per cent voids.	Weight per cu. ft.	Weight per cu. yd.	Per cent dirt.	Per cent of total sample tested (minus ¼-mesh).	Locality.
50	40	30	20	10									
8.83	44.75	85.35	95.41	99.91	0.20	2.20	2.61	45.9	88.25	2383	5.30	Total	Ellis pit, Commerce, Scott Co.
1.72	2.86	3.95	5.85	53.03	1.05	1.60	2.63	33.7	108.98	2935	0.60	Total	Ellis pit, Commerce, Scott Co.
4.76	19.38	29.06	43.67	97.84	0.20	5.65	2.61	46.1	87.92	2374	10.60	Total	Ellis pit, Commerce, Scott Co.
8.68	99.09	99.42	99.59	100.00	0.07 −	1.00 +	2.63	58.8	67.72	1828	.....	Total	Near Commerce, Scott Co.
7.68	90.96	98.07	100.00	100.00	0.16	1.49	2.636	48.0	85.5	2308	0.20	Total	Commerce sandstone, Scott Co.
8 30	23.20	36.90	42.20	61.60	0.32	5.20	2.62	35.0	106.0	2862	10.00	— ¼ = 67 per cent	Ellis pit, Commerce, Scott Co.
4.50	28.20	34.60	39.90	58.40	0.06‡	12.00 +	2.57	33.0	107.6	2907	24.00	— ¼ = 27 per cent	Benton pit, Benton, Scott Co.
3.10	27,50	41.90	68.30	77.80	0.25	2.92	2.61	41.0	96.2	2597	7.25	— ¼ = 47 per cent	Glassstetler pit, Benton, Scott Co
7.10	30.10	36.50	46.70	70.10	0.10	12.30	2.60	34.0	107.2	2894	29.00	— ¼ = 21 per cent	Williams pit, Stoddard Co.
9.90	15.20	30.40	41.80	61.70	0.28	5.70	2.61	35.0	106.2	2867	6.00	— ¼ = 37 per cent	Wetherholt pit, Dunklin Co.
9.60	27.20	37.60	49.90	63.20	0.19	6.50	2.62	32.0	111.3	3005	11.0	— ¼ = 32 per cent	Dalton pit, Dunklin Co.
7.60	15.90	52.30	74.90	85.00	0.32	1.87	2.62	39.0	99.8	2695	15.5	— ¼ = 47 per cent	Dexter pit, Stoddard Co.

AL SANDS AND GRAVELS.

sieve.					Effective size.	Uniformity coefficient.	Specific gravity.	Per cent voids.	Weight per cu. ft.	Weight per cu. yd.	Per cent dirt.	Percentage of total sample tested (minus ¼-mesh).	Locality.
50	40	30	20	10									
4.99	6.44	10.59	20.43	53.34	0.50	3.60—4.60	2.60	43.9	91.3	2460	5.0	— ¼ = 77 per cent	Maryville, Nodaway Co.
6.15	11.45	33.35	80.95	100.00	0.36	1.82	n.d	n.d.	n.d.	n.d.	6.0	Total	Maryville, Nodaway Co.
8.24	10.15	19.15	33.40	52.20	0.38	5.13—8.94	2.60	36.6	103.0	2781	5.9	— ¼ = 67 per cent	Guilford, Nodaway Co.
2.67	5.43	17.27	46.75	87.35	0.44	2.36	2.61	41.3	96.2	2597	3.9	Total	Worthington, Putnam Co.

A. The Jake Thompson pit, Guilford, Nodaway County. Shows cross bedding in glaciofluvial (Aftonian?) gravel.

B. A detail of the above cross bedding.

OTHER OCCURRENCES OF GLACIO-FLUVIAL SANDS AND GRAVELS.

Near Rockport in Atchison County, along the Missouri River bluffs in sec. 22, T. 64 N., R. 41 W., on the land of J. M. Whitham, gravels of a similar nature have been worked locally. Eighteen feet of the material is exposed in the pits, and according to George L. Smith,[1] it carries a rich fauna of Aftonian age. It is on this authority that the gravels underlying the till of Nodaway County were mentioned as being also of this age. Similar but coarser stratified gravels overlain by till are reported from near Smithville in Clay County, but no details of their occurrence are to be had.

Mr. F. C. Greene[2] of this Bureau reports the same type of material also from Putnam County, where it is worked locally. He furnished the writer with the following sample:

Sample 207.—This sample was taken from a small pit near Worthington in the SW. ¼ SW. ¼ sec. 34, T. 65 N., R. 16 W., in Putnam County along the west side of Chariton River. The sand is chiefly quartz and flint with small fragments of limestone, quartzite, and various igneous rocks. The material is stratified, lens-like, and overlain by till. There is some development for local use. The material all passed the ¼-inch screen. About 12 per cent was retained on the 10-mesh and 98 per cent on the 60-mesh screen. The effective size is 0.44 mm. and the uniformity coefficient 2.36. The sp. gr. is 2.61, voids 41.3 per cent, weight per cu. ft. 96.2 lb., and weight per cu. yd. 2597 lb. Washing removes 3.9 per cent dirt and leaves the sand grains clear and free from clay film. The screen tests are tabulated on p. 206.

Mr. Greene also notes the occurrence of 75 feet of similarly stratified gravel and sand overlain by till in eastern Grundy County near Lindley, where it is used locally as a source of building material.

Shumard[3] reports over 50 feet of glacial sand and gravel on Fox Creek in Clark County.

Stratified gravel and sand are also reported (same volume) from Shelby, Macon, and other counties, but are not described.

[1] Atchison County Mail, Feb. 3, 1915.
[2] Unpublished notes.
[3] Reports of the Geological Survey of the State of Missouri, p. 316, 1873.

Such stratified glacio-fluvial gravels are widespread north of Missouri River, especially over the western two-thirds of the State.

TILL GRAVELS.

In many places in the northern States there is a heavy production of gravel and sand from pockets of material enclosed in typical till of the morainal belts. Such material doubtless occurs at places in Missouri, but no details of occurrences are at hand, and the writer does not know of any points where such gravels are being developed commercially.

THE SOUTH ST. LOUIS MOULDING SANDS.

There occurs in the neighborhood of Carondelet Station in south St. Louis an extremely fine-grained, argillaceous sand, which has extensive local use for moulding sand. This material is capped by from one to forty or fifty feet of loess, from which it is separated by a distinct line of demarcation. The age of the material is probably either Pleistocene or Recent, its position beneath the base of the loess pointing rather to the former. It is extremely fine, with faint lines of stratification, and was probably laid by water. Its exact age and mode of origin are matters to be determined when the superficial geology of the Carondelet region is worked out in much more detail than it is at present. The material is exposed in many basements and road cuts in the vicinity, and foundries in the area are said to produce their own moulding sands. The following company is the only regular producer who has reported:

Allen, John W., and Son.—This firm operates two pits, one at Pennsylvania and Haven Sts. (Pl. XXXVIII, A), the other at Reilly and Prim (Pl. XXXVIII, B), in the southern part of St. Louis. The loess overburden is about four feet thick and is stripped back with team and scraper. At both pits the sand is shoveled into wagons by hand and hauled with teams. The pit at Pennsylvania and Haven has a small crusher for breaking up the harder lumps. The material is used exclusively for moulding sand. By careful selecting, two grades are possible, an open and a close. Most of the output is used in St. Louis, but some sand has been shipped to more distant points.

Plate XXXVIII shows the contact of the loess overburden of these pits with the underlying sand. The material of these

A. J. W. Allen and Son's moulding sand pit, Pennsylvania and Haven Streets, Carondelet, South St. Louis.

B. J. W. Allen and Son's moulding sand pit, Reilly and Prim streets, Carondelet, South St. Louis.

pits was sampled and chemical analyses and screen tests are shown on the following pages:

Analyses of moulding sand from South St. Louis.

Sample 156.

SiO_2	80.30
Al_2O_3	6.83
Fe_2O_3	3.67
CaO	1.78
MgO	0.88
Alkalies	4.71
Ignition	2.12
	100.29

Sample 157.

SiO_2	82.24
Al_2O_3	8.40
Fe_2O_3	1.04
CaO	1.26
MgO	0.64
Alkalies	4.89
Ignition	1.74
	100.21

Both of these sands are much higher in alkalies than the theoretical limit given on pp. 73-77.

Screen tests of moulding sand from South St. Louis.

Sample 156, Pennsylvania and Haven Sts.

Thru.	On.	Per cent.	Screen.	Total thru.	Total on.
30	40	0.27	40	99.73	0.27
40	50	0.23	50	99.50	0.50
50	60	0.33	60	99.17	0.83
60	70	0.53	70	98.64	1.36
70	80	0.94	80	97.70	2.30
80	90	0.80	90	96.90	3.10
90	100	13.79	100	83.11	16.89
100	150	29.21	150	53.90	46.10
150	200	4.89	200	49.01	50.99
200	Pan	49.01	Pan	00.00	100.00

Sample 157, Reilly and Prim Sts.

Thru.	On.	Per cent.	Screen.	Total thru.	Total on.
30	40	0.23	40	99.77	0.23
40	50	0.23	50	99.54	0.46
50	60	0.30	60	99.84	0.76
60	70	0.46	70	98.78	1.22
70	80	0.61	80	98.17	1.83
80	90	0.84	90	97.33	2.67
90	100	4.76	100	92.57	7.43
100	150	30.91	150	61.66	38.34
150	200	10.20	200	51.46	48.54
200	Pan	51.46	Pan	00.00	100.00

LOESS MOULDING SANDS.

Near Herculaneum, at the quarry of the Enterprise Sand and Mining Company, moulding sand is being secured from the contact of the loess with the St. Peter sandstone. The sand consists largely of St. Peter sand grains, with enough loess to serve as a binder.

Sample 38.—The sand has an effective size of 0.1 mm. and a uniformity coefficient of 2.92. The analysis follows:

Analysis of moulding sand from Herculaneum.

SiO_2	91.52
Al_2O_3	4.00
Fe_2O_3	1.34
CaO	tr.
MgO	0.59
Alkalies	1.69
Ignition loss	2.46
	101.60

This sand is somewhat lower in bond (Al_2O_3) and higher in alkalies than the theoretical limits given on pp. 73-77. The screen test on this sand follows:

Screen test of Herculaneum moulding sand.

Sample 38.

Thru.	On.	Weight.	Per cent.	Screen.	Total thru.	Total on.
10	20	0.05 grm.	0.06	20	99.94	0.06
20	30	1.17 "	1.47	30	98.47	1.53
30	40	13.80 "	17.33	40	81.14	18.86
40	50	16.20 "	20.35	50	60.79	39.21
50	60	17.70 "	22.25	60	38.54	61.46
60	70	3.48 "	4.37	70	34.17	65.83
70	80	7.45 "	9.36	80	24.81	75.19
80	90	1.65 "	2.07	90	22.74	77.26
90	100	3.60 "	4.52	100	18.22	81.78
100	150	6.20 "	7.79	150	10.43	89.57
150	200	1.15 "	1.44	200	8.99	91.01
200	Pan	7.16 "	8.99	Pan	0.00	100.00
		79.61	100.00			

RECENT SANDS AND GRAVELS.

RESIDUAL DEPOSITS.

Over most of those portions of Missouri where the Mississippian and older formations outcrop, the residual clays are highly flinty, and where this flint is abundant, the material constitutes a fairly good road gravel.[1] These "hardpan" gravels are very widely distributed, and are only of local value. To this type belongs the small gravel pit located near Daisy in Cape Girardeau County, and possibly also the "Silica" pit previously described (p. 173) at Wittenberg in Perry County. This latter material, however, differs so widely from any typical residual deposit, that it has been thought best to describe it under the Devonian formations, from which it is derived.

The granite residual described on p. 89 might also be referred to the recent deposits.

RIVER AND CREEK SANDS AND GRAVELS.

The most important sources of building sand and gravel in Missouri are the streams. These vary widely in character from place to place, and for purposes of discussion, it has been found convenient to divide the production into the following districts: Mississippi River, Missouri River, Ozark streams, glaciated Pennsylvanian areas, unglaciated Pennsylvanian areas, glaciated areas older than the Pennsylvanian, unglaciated Mississippian areas, and the southeast lowlands.

MISSISSIPPI RIVER.

In 1913 the Mississippi yielded 25 per cent of the weight and 20 per cent of the value of the total sand production of the State.

No microscopic examination was made of these sands and no effort put forth to determine their quantitative mineralogic composition. The larger pebbles consist dominantly of flint with smaller proportions of quartzite, trap, porphyry, granite, gniess, and schists of various types. Among the smaller grains, quartz is the most conspicuous, and flint next, while feldspar, ferro-magnesian minerals, and small fragments of various

[1]Buckley, E. R., Missouri Bureau of Geology and Mines, vol. 5, 2d series, pp. 19-20, 1907.

igneous rocks make up the remainder. The sand has a gray, mottled appearance. The grains vary from sharp to perfectly rounded, but on the average are subangular and fairly smooth.

As all sands secured from the Mississippi were dredged by means of centrifugal pumps, the screen tests do not indicate the true average for the natural sand, but only the average of the material as placed on the market, since the fines were largely washed out in the overflow.

Of the sands tested from the Mississippi, from 5 to 70 per cent is retained on the 10-mesh sieve, and from 67 to 99.7 per cent on the 60-mesh. The effective size varies from 0.15 to 0.51 mm. and the uniformity coefficient from 1.87 to 7.75; but the latter lies chiefly between 2.00 and 3.00. The specific gravity varies from 2.63 to 2.65, the voids from 27.8% to 39.4 per cent, the weight per cubic foot from 100.3 lb. to 118.7 lb., and per cubic yard from 2709 to 3205 lb. The removable dirt content varies from 0.3 per cent to 2.3 per cent, but it must be remembered that all of these samples have passed through the centrifugal pumps, by means of which much silt and fine sand have been removed. Bar-run samples would doubtless average a higher dirt content.

Very little gravel is removed from the Mississippi, the only regular production coming from Hannibal, where it is pumped opposite the mouths of small creeks which build bars into the river. An analysis of a typical sand, dredged from the Mississippi at St. Louis, is given herewith.

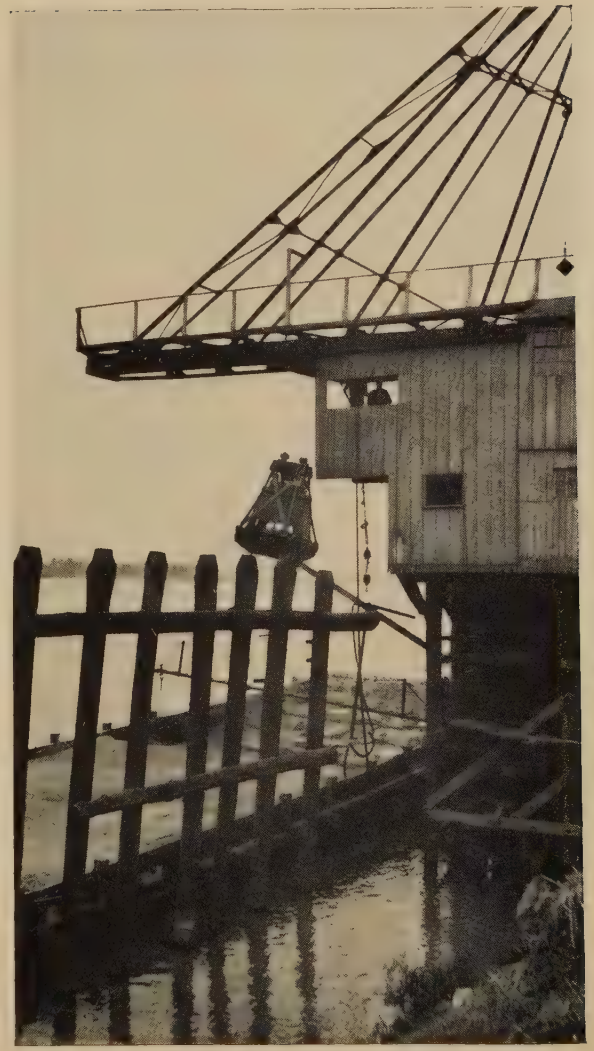
Analysis of Mississippi River sand.

SiO_2	86.14
Al_2O_3	5.51
Fe_2O_3	1.27
CaO	1.30
MgO	0.51
Alkalies	4.14
Ignition	1.16
	100.03

Mississipp River sand when properly washed and screened is suitable for practically all building operations. There has been some objection to it because it was not considered sufficiently sharp, but with the decreasing emphasis on sharpness, this objection is becoming of little importance.

Below the mouth of the Missouri there is some complaint about lignite in the sand. This is said to cause popping on the

A. Dredge pump of the Universal Sand Company, Crystal City, Jefferson County.



B. Plant of Meramec Portland Cement and Materials Company, foot of Dock Street, St. Louis, on Mississippi River. Shows clam shell in operation.

surface of sidewalks and plaster, but it is not objected to in heavy, rough work. Above Missouri River the lignite is not reported.

Sand is dredged from Mississippi River at Cape Girardeau, Crystal City, St. Louis, Louisiana, Hannibal and Canton. Descriptions of the various plants operating along the river follow:

Morrison Ice and Fuel Company, Cape Girardeau.—This plant is located on the bank of the Mississippi River, about four or five blocks up stream from the St. Louis and San Francisco station. The sand is pumped from the river by one 6-inch centrifugal dredge pump, hauled on barges to the plant, and elevated by means of a cable car which dumps automatically into bins built over a wagon drive way and a spur of the railroad, loading being done through chutes into the car or wagon.

The only washing the sand undergoes is through the pump. As the material flows from the pump onto the barge, much of the silt and finer sand is washed overboard with the overflow. A ¼-inch mesh screen at the discharge causes the coarser material to run back into the river. The capacity of the plant is 100 yards per day. The sand is used chiefly in concrete, lime mortar, and to some extent, in brick work.

About half their output is used in Cape Girardeau, the remainder goes to the small towns in southeast Missouri and a little into northeastern Arkansas.

A sample of the sand from this plant shows the following characteristics:

Sample 150.—This sample was secured from the loading bin. The material passes over a ¼-inch screen at the dredge. Five per cent of the sand is retained on the 10-mesh and 66 per cent on the 60-mesh. The effective size is 0.15 mm. and the uniformity coefficient 2.42. Sp. gr. is 2.64, voids 36.9 per cent, weight per cu. ft. 104.1 lb., and weight per cu. yd. 2811 lb. Washing removes 0.36 per cent dirt. The complete screen test is given on p. 224.

Universal Sand Company, Syndicate Trust Building, St. Louis.—This Company operates a sand plant on the Mississippi, 1½ miles north of Crystal City, Jefferson County, and a gravel plant on Meramec River.

The sand, at the Crystal City plant, is pumped from the river with a centrifugal dredge pump (Pl. XXXIX, A). The dredge is anchored near the bank, and a pipe line laid to a large

tank on the shore. The sand is pumped directly into the tank, where it is washed and loaded on the cars. The sand is passed over a ½-mesh screen at the pump, the coarse pebbles being returned to the river.

About 5 cars a day, washed but not graded, are produced and shipped for structural purposes, concrete, brick laying, plastering, etc. About 5 to 6 cars a day are furnished to Mr. H. B. Straight, Crystal City, who operates a grading plant. The plant has a spur of the Mississippi River and Bonne Terre railroad.

Straight, H. B., Crystal City.—This plant (Pl. XI, B) is located 1½ miles north of Crystal City, Jefferson County, close to the plant of the Universal Sand Company. Mr. Straight secures his sand from the Universal Sand Company, who pumps it from the Mississippi directly into the washing tank without screening. Mr. Straight has a screening and washing tower. The sand is put through four washing processes, one with steam, and is graded wet through a series of screens. Further details of the process have not been made public. The claim is made that this is the only plant in the United States which can satisfactorily grade wet sand. Mr. Straight is prepared to put out a large number of grades of sand, the chief ones being asphalt sand (very fine), dollar pavement (½-inch to 8-mesh), sand blast sand, core sand (smaller than 1 mm.), engine sand (smaller than 0.35 mm.) used in sanding tracks, and filter sand. The largest part of the trade is in core sand and filter sand. This is the only filter sand plant in the State.

The plant is on a spur of the Mississippi River and Bonne Terre Railroad. The plant has furnished filter sand to St. Louis, Mo., Louisville, Ky., Evanston, Ill., and Cheyenne, Wyo., as well as to other smaller places. Mr. Straight kindly sent us samples of the various grades he is producing. The following sample of river-run sand was tested:

Sample 213.—This sample had been taken from the centrifugal pump screened over ½-inch screen, and had undergone no further washing. About 12 per cent is retained on the 10-mesh and 95 per cent on the 60-mesh sieve. The effective size is 0.26 mm. and the uniformity coefficient 2.46. The sp. gr. is 2.65, the voids constitute 37.1 per cent, and the sand weighs 104.3 lb. per cu. ft., or 2816 lb. per cu. yd. Washing removed 0.3 per cent dirt. Screen tests on this sand are tabulated on p. 224. Mr. Straight also submitted three grades of

A. Plant of Meramec Portland Cement and Materials Company, foot of Dock Street, St. Louis, on Mississippi River. Shows belt conveyor and loading hopper.

B. Plant of Union Sand and Materials Company, foot of Tyler Street, St. Louis, on Mississippi River. Clam shell unloading barge.

screened sand, fine, medium and coarse. He reports the medium grade to have an effective size of 0.4 to 0.5 mm. and a uniformity coefficient of 1.65. He also reports this sand to run 98½ per cent silica, and less than 3 per cent of lime and magnesia, computed as carbonates. His coarse sand is screened over a 9-mesh, the medium through 9 and over 20-mesh, the fine through 20-mesh.

Meramec Portland Cement and Materials Company, Syndicate Trust Building, St. Louis.—This Company operates a sand plant on Mississippi River at the foot of Dock St., St. Louis, in St. Louis County, and a gravel plant on the Meramec River at Sherman, St. Louis County. The sand at the St. Louis plant is pumped with a 15-inch centrifugal dredge pump, towed to the plant in barges, and elevated in a clam shell (Pl. XXXIX, B) to a belt conveyor which carries it to the loading hoppers from whence it can be loaded directly into the cars by chutes (Pl. XL, A). The only washing is at the pump, where the silt and finer sand are partly removed in the overflow from the barges. At the barge, the said is passed over a coarse screen to remove the coarser material, which goes back into the river. The chief uses are for plastering, concrete, and brick work. Most of the output is sold in St. Louis. The following sample was taken by the writer directly from the loading hopper:

Sample 155.—Of this sand, about 25 per cent is retained on the 10-mesh and 99.7 per cent on the 60-mesh. The effective size is 0.51 mm. and the uniformity coefficient 2.40. The sp. gr. is 2.63, there are 35.6 per cent voids, and the sand weighs 105.8 lb. per cu. ft., or 2858 lb. per cu. yd. Washing showed 0.5 per cent dirt. The screen tests are given in full on p. 224.

Union Sand and Materials Company, International Life Building, St. Louis.—This Company operates sand plants at St. Louis, Mo., Hannibal, Mo., and Memphis, Tenn. It also operates a gravel plant at Drake on Meramec River.

St. Louis plant of the Union Sand and Materials Company.—This plant (Pl. VII, B) is located at the foot of Tyler St., St. Louis, in St. Louis County. The sand is pumped from the Mississippi with one 15-inch centrifugal dredge pump, towed on barges to the plant, dipped from the barge with clam shell dipper (Pl. XL, B), hoisted into a hopper, from which it runs onto a belt conveyor and is carried either to the loading hoppers or to a stock pile. Hoppers load directly into the cars by means of chutes. The only washing is that at the pump. As it runs

onto the barge from the pump, most of the mud and a considerable amount of the finest sand are carried back into the river by the waste water. The sand is pumped onto a coarse screen, which takes out the coarser material and allows it also to go back into the river. Most of the sand from this plant is used in concrete, brick work, plastering, and as core sand. Most of the output is used in St. Louis and vicinity. The following sample was taken by the writer from the stock pile at the plant:

Sample 154-A.—Fourteen per cent of this sand is retained on the 10-mesh and 93 per cent on the 60-mesh sieve. The effective size is 0.26 mm. and the uniformity coefficient 2.77. The sp. gr. is 2.635, the voids 36.5 per cent, weight per cu. ft. 104.6 lb., and weight per cu. yd. 2824 lb. Washing removed 1.1 per cent dirt, which is unusually high for samples washed through centrifugal pumps. Screen tests are given on p. 224.

Hannibal plant of the Union Sand and Materials Company.—This plant is located on the bank of Mississippi River, about eight blocks north of the Union Station in Hannibal, Marion County (Pl. XLI, A). The sand is pumped from Mississippi River with a 15-inch centrifugal dredge pump, towed on barges to the plant, dipped from the barge with a 5-yard clam shell dipper and dumped on a washing table, where it is washed with an 8-inch stream of water, and screened with a system of stationary inclined screens, over which the sand and gravel run by gravity. The silt and finer sand are washed down the wasteway into the river. The finished product runs into hoppers, from which it can be loaded directly into cars or wagons. The material dredged in the main channel is mostly sand, but off the mouths of certain creeks, large gravel bars have been worked. Various size screens are used to produce the desired grades of sand or gravel. The chief output has been used for ballast. Considerable concrete gravel and building sand have also been produced, together with a little roofing gravel and binder gravel. The capacity of this plant is about 50 cars a day, most of which is used locally. The plant was idle when visited during the summer of 1913, but samples of the sand and gravel were secured.

Sample 159.—This sample of sand was taken from the hopper of the plant, and has passed over a ¼-inch screen. About 14 per cent is retained on the 10-mesh and 93 per cent on the 60-mesh sieve. The effective size is 0.28 mm. and the uniformity coefficient 2.70. The sp. gr. is 2.64, the voids constitute 38.3 per cent, the sand weighs 101.8 lb. per cu. ft., or 2749 lb. per

A. Plant of Union Sand and Materials Company, Hannibal, Marion County, on Mississippi River.

B. Plant of Canton Fuel Company, Canton, Lewis County, on Mississippi River. Discharge of water and sand at stock pile.

cu. yd. The sand washes 2.3 per cent dirt, the highest dirt content noted in any sand washed through the pumps. This was due largely to the presence of clay lumps plainly visible in the sand. These lumps went to pieces and were removed by continued washing. (For complete screen tests see table, p. 224).

Sample 160.—This is the only sample of gravel secured from the Mississippi, and was taken from a pile of gravel at the plant. It was dredged from a bar at the mouth of a small creek entering from the Missouri side. Only 28 per cent passed the ¼-inch screen. The plus ¼-inch material was largely flint, but carried a little foreign igneous material. Of the minus ¼-inch product, about 70 per cent was retained on the 10-mesh and 97 per cent on the 60-mesh sieve. The effective size is 0.49 and the uniformity coefficient 7.75. The sp. gr. is 2.635, the voids 27.8 per cent, the weight 118.7 lb. per cu. ft., or 3205 lb. per cu. yd. Washing removed 1.7 per cent dirt. This sample showed the lowest voids, the highest uniformity coefficient, and the greatest weight per cubic foot of any sample of Mississippi sand examined. (For complete screen tests, see table, page 224).

Canton Fuel Company, Canton.—This plant is located at Canton, Lewis County. The sand is pumped with a 4-inch centrifugal dredge pump anchored a short distance from the bank. A 400-foot pontoon pipe line (Pl. V, A) carries the sand directly to a stock pile on the bank (Pl. XLI, B) from which it is shovelled into wagons by hand. The Company plans to put in a spur of the Burlington and a loading hopper. The sand is not screened except by a 2½-inch screen over the intake to keep out occasional coarse material, and the only washing is through the pump. The capacity of the plant is about 6 cars daily. The sand is used for cement work, plastering, and brick work, but for the latter uses, is usually screened by the users. A small amount is used locally for bedding stock cars. Most of the output is consumed locally, but occasional shipments are made to Kirksville and other towns and cities near Canton. The market lies entirely to the west in the prairie towns, where the local supply of sand is generally scarce.

Sample 162.—This sample was taken directly from the pile of sand at the discharge of the pump. Of this sand 8 per cent is retained on the 10-mesh and 99 per cent on the 60-mesh screen. The effective size is 0.50 mm. and the uniformity coefficient 1.87. The sp. gr. is 2.64, the voids 38.3 per cent, the weight per cu,

ft. 101.8 lb., and the weight per cu. yd. 2749 lb. Washing removed 0.38 per cent dirt. The complete screen tests are given in the table on p. 224.

Louisiana Sand and Gravel Company, Louisiana.—This plant is located several blocks north of the Burlington Station, on the river bank in Louisiana, Pike County. The sand is pumped from Mississippi River by one 6-inch centrifugal dredge pump, is towed to the plant on a barge, and shovelled by hand from the boat on to a belt conveyor which unloads either on to a stock pile or into the cars. The sand is not screened and has no other washing than that which it receives in passing through the pump. The capacity of the plant is about 10 cars per day. The Company is now contemplating building a plant with clam shell and loading hoppers. The sand is used chiefly for plastering, brick laying, and concrete work. This plant supplies the local market, and ships a considerable amount to Bowling Green, Mexico, and other prairie towns to the west where sand is scarce.

Sample 163.—This sample was taken directly from the Company's stock pile. Of this sand, 5 per cent is retained on the 10-mesh and 93 per cent on the 60-mesh screen. The effective size is 0.25 mm. and the uniformity coefficient 202.. The sp. gr. is 2.65, voids 39.4 per cent, weight per cu. ft. 100.35 lb. and weight per cu. yd. 2709 lb. Washing removes 0.5 per cent dirt. Screen tests are given in full in the table, p. 224.

MISSOURI RIVER.

During the year 1913 Missouri River alone furnished 35.3 per cent of the weight and 31.4 per cent of the value of the total sand production of the State.

As with the Mississippi sands, no petrographic studies were made and no quantitative mineralogic determinations attempted, but in a general way it may be said that the mineralogic content of the two sands is not very different. The larger pebbles of the Missouri sands carry very much flint and smaller amounts of quartzite and foreign igneous pebbles. The finer portions are largely quartz, with considerable admixture of flint and appreciable quantities of igneous material. On the whole, the sands of the Missouri carry more silt and are finer than those of the Mississippi, and sites for pumping must be selected with more care. The sands of the Missouri also carry considerable quantities of lignite, which are thought deleterious (see pp. 11, 52, 53),

especially for plastering and sidewalk work where the coal causes the popping of the surface.

The grains vary from thoroughly rounded to sharply angular, and the sand can best be described as subangular. As with the Mississippi, most of the Missouri sands were dredged by means of centrifugal pumps, and much silt and fine sand were washed out in the overflow. Of two samples taken directly from the bar, unwashed but carefully selected, each washed 2.8 per cent dirt. Pumped samples vary between 0.38 and 1.10 per cent. Effective size varies from 0.14 to 0.27 mm. and uniformity coefficient from 1.51 to 5.1, usually ranging about 2.00. From 1 per cent to 17 per cent is retained on the 10-mesh screen and from 38 per cent to 96 per cent on the 60-mesh. The specific gravity varies from 2.62 to 2.64 and the voids from 33.9 to 42.0 per cent. The weight per cubic foot varies between 95.7 pounds and 108.2 pounds, the weight per cubic yard between 2584 and 2922 pounds.

The following is an analysis of a Missouri River sand dredged at Kansas City.

Analysis of Missouri River sand.

SiO_2	83.32
Al_2O_3	6.20
Fe_2O_3	1.08
CaO	1.24
MgO	0.51
Alkalies	4.13
Ignition	1.06
	97.54

So far as the writer could learn, there is no production of gravel from Missouri River. Sand, however, is being dredged at St. Charles, Jefferson City, Boonville, Glasgow, Lexington, Kansas City and St. Joseph. A description of the plants along this river follows.

Pundmann, Theo., St. Charles, St. Charles County.—At low water teams drive onto the bar, wagons are loaded by hand, and the sand is hauled to a vacant lot and stock-piled. The sand is not washed or screened. The average business is reported as about 4,000 or 5,000 yards per year. Mr. Pundmann has a 6-inch dredge pump, but does not operate it, as he says that for local use he can get the sand out more cheaply with teams. The chief uses are for cement work, plastering, and brick laying. The entire output is consumed locally.

Sample 158.—This sample was secured directly from the stock pile. The sand is as it came from the bar, being neither washed nor screened. About 17 per cent is retained on the 10-mesh sieve and 84 per cent on the 60-mesh. The effective size is 0.17 mm. and the uniformity coefficient 5.10. The sand has a sp. gr. of 2.62, 33.9 per cent of voids, and weighs 108.2 lb. per cu. ft., or 2922 lb. per cu. yd. Washing removes 2.8 per cent dirt but fails to remove the lignite, which is present in considerable quantity. Because this sand is secured from the bar by hand and can be selected, Mr. Pundmann is able to put out one of the coarsest sands placed on the market from Missouri River. It has the highest uniformity coefficient and the lowest voids. (See screen tests in table, p. 224).

Jefferson City Sand and Gravel Company, Jefferson City, Cole County.—The sand is pumped from Missouri River with a 10-inch centrifugal dredge pump (Pl. XLII, A), towed on barges to the plant, and unloaded with a 1½ yard clam shell directly onto the cars, or the stock pile (Pl. XLII, B). The clam shell is so arranged that it can also be used for loading from the stock pile into the cars.

The only washing is through the pump, the waste water carrying out much of the silt and finer sand as it overflows from the barge. A ¼-inch screen at the discharge removes the gravel, which runs back into the river. The capacity of the plant is 500 yards per day. The sand is used for cement work, plastering, and brick laying. The Company has a spur of the Missouri Pacific Railroad. Most of the output is used in Jefferson City, occasional shipments being made to California, Hermann, Otterville, and other small nearby towns.

Missouri River Sand and Gravel Company, Boonville, Cooper County.—Sand is pumped from Missouri River with a 10-inch centrifugal dredge pump, towed on barges by drum and cable to the plant, and handled with 2-yard clam shell (Pl. VI, A) which loads either directly onto the cars, or onto stock piles from which it can be loaded to the cars with the same clam shell. The only washing is through the pump, the silt and finer sand being washed overboard by the overflow. A ½-inch screen at the barge removes the coarser pebbles, which are dumped back into the river. A capacity of 1000 yards per day is reported. The sand is used chiefly for cement work, plastering, and brick laying. The company has a spur of the Missouri Pacific Railroad. About two-thirds of the output is shipped. The chief

A. Dredge pump in operation, Jefferson City Sand and Gravel Company, Cole County, on Missouri River.

B. Crane and clam shell in operation, Jefferson City Sand and Gravel Company, Cole County, on Missouri River.

markets are at Sedalia, Moberly, Columbia and other nearby towns, though shipment has been made to Hannibal.

Donnivant, Chas., Boonville, Cooper County.—Mr. Donnivant operates one barge and a steam towboat. The sand is shovelled by hand from the bar to the barge, or handled in wheelbarrow when necessary, and unloaded on the stock pile. He can operate only at low water when good bars are uncovered. He reports that he and four helpers can get out from 15 to 25 yards daily in this way. The sand is unwashed and unscreened, and is used for plastering, brick laying, and cement work, the entire output being used in Boonville.

Glasgow Sand Company, Glasgow, Howard County.—The sand is pumped from Missouri River with an 8-inch centrifugal dredge pump, towed to the plant on barges, and loaded with a 3-yard clam shell dipper, which puts the sand directly on the cars or on a stock pile from which it can be loaded to the cars by means of the clam shell. The only washing is through the pump, the overflow from the barge washing out the mud and finer sand. It is screened at the barge through a ½-inch mesh. The chief uses are for bricklaying, plastering, and cement work. The Company has a spur of the Wabash Railroad. About one-third of the output is used in Glasgow, the remainder being shipped to Moberly, Mexico, and other nearby towns.

Sample 182.—The sand is screened over a ½-inch screen at the pump. As put on the market, 8.36 per cent is retained on the 10-mesh, and 92.15 per cent on the 60-mesh screen. The effective size is 0.23 mm. and the uniformity coefficient 2.80. The sand has a sp. gr. of 2.635, and 35.1 per cent of voids. The weight per cu. ft. is 106.9 lb., and per cu. yd. 2886 lb. Washing removes 0.75 per cent of dirt. (For complete screen tests, see table, p. 224.)

Lexington Triumph Press Brick Company, Lexington, Lafayette County.—At low water, teams drive onto the bar, wagons are loaded by hand, and the sand is stock-piled for the season. The product is neither washed nor screened. The sand is used for plastering, bricklaying, and cement work. The entire output is used in Lexington.

Sample 181.—This sample was taken from a load of sand being delivered by the Company to a customer. All the sand passed the 10-mesh, and 80 per cent was retained on the 60-mesh sieve. The effective size is 0.18 mm. and the uniformity coefficient 2.80. The sp. gr. is 2.63, the voids 37.2 per cent, and

the sand weighs 103.3 lb. per cu. ft., or 2787 lb. per cu. yd. Washing removed a dirt content of 2.8 per cent. (For complete screen tests, see table, p. 224.)

Stewart-Peck Sand Company, Kansas City, Jackson County.—The sand is pumped from Missouri River with a 10-inch centrifugal pump (Pl. XLIII, A), towed to the plant on barges, and unloaded with a 3½-yard clam shell (Pl. VIII, A). The sand is loaded from the barge directly to cars, or to a stock pile (Pl. XLIII, B), from which it can be loaded onto the cars with the clam shell. The only washing is that given it during pumping, the silt being washed out by the overflow from the barge. A ½-inch screen at the discharge removes the coarser material, which runs back into the river. A similar extra clamshell is sometimes used.

When operating both dippers the capacity is about 50 cars per day. The sand is used for plastering, brick laying, and cement work. Little is used for nicely finished surfaces on account of the lignite, Kaw River sand being better suited to this class of work. A fine sand procured by properly selecting the bars from which to pump, is used for radiator core sand. A small part of the output is used for engine sand and for bedding stock cars. The plant has a spur of the Missouri Pacific Railroad. About one-fourth of the output is used locally. Little sand is shipped north, since St. Joseph supplies this demand, but a good deal is shipped south to Springfield and intermediate points.

Sample 164.—The sand from which this sample was taken is the coarsest grade secured at Kansas City. At the barge the sand is screened over a ½-inch sieve. As put on the market 2 per cent is retained on the 10-mesh and 92 per cent on the 60-mesh sieve. The effective size is 0.23 mm. and the uniform coefficient 1.90. The sand has a sp. gr. of 2.63, 38.5 per cent voids, and weighs 101.9 lb. per cu. ft., or 2729 lb. per cu. yd. Washing removes 0.75 per cent dirt. (See screen table, p. 224).

Sample 165.—This is a finer sand than the preceding and the sample was taken also from the stock pile of the Stewart-Peck Company. One per cent is retained on the 10-mesh and only 63 per cent on the 60-mesh screen. The effective size is 0.15 mm. and the uniformity coefficient 2.00. The sp. gr. is 2.64, the voids 40.5 per cent and the sand weighs 98.2 lb. per cu. ft., or 2651 lb. per cu. yd. Washing removed 0.4 per cent dirt. (For complete screen tests, see table, p. 224.)

A. Dredge boat of Stewart Peck Sand Company, Kansas City, on Missouri River.

B. Crane and clam shell stock-piling sand, Stewart Peck Sand Company, Kansas City, on Missouri River.

A. Plant of Pioneer Sand Company, St. Joseph, Buchanan County, on Missouri River.

B. Dredge Boat of Universal Sand Company, Pacific, Franklin County, on Meramec River.

The Materials Laboratory of the U. S. Geological Survey at St. Louis made the following tests on sands from Kansas City.[1] The Kaw River sand is given merely for comparison.

"*Register No. Sd. 1.*—A recent river sand, designated Sd.1, was pumped from the Missouri River channel at Kansas City, Mo., and discharged upon scows in which it was transported to Kansas City. An endeavor was made to procure the sand in its original condition, so as to determine the proportion of silt and its consequent effect on mortars in which the sand was used, but this was found practically impossible, as a large amount of the silt was washed away in pumping, and when received at the laboratories the determination showed only 0.2 per cent of silt. While this does not indicate the amount of silt present in the original sand, it does show the condition of the sand marketed. It is reported to be used for all purpo es except that it is unsuited for finishing work because of a tendency to check or peel off.

"An examination of the granularmetric analysis curve proves this material to be one of the 'finest' sands received at the laboratories."

The following figures are taken from the tables accompanying the above description. Three per cent was retained on the 10-mesh, and about 79 per cent on the 50-mesh sieve. The percentage of voids is 32.5, the sp. gr. 2.64, the weight per cu. ft. 109.3 lb., per cu. yd. 2951 lb., and the uniformity coefficient is 5.465.

"*Register No. Sd. 2.*—Another recent river sand, designated Sd.2, was obtained from the channel of Kansas (Kaw) River, at Armourdale (a part of Kansas City, Kans.), by means of a dredge and pump, and discharged into a scow.

"The granularmetric analysis curve indicates that about 70 per cent passes the No. 20 sieve and about 15 per cent passes the No. 40 sieve. The percentage of voids is 34.9, the weight per cu. ft. is 107.7 pounds, there is only a trace of silt, and the yield in 1.3 mortar is 1.12."

The sp. gr. is 2.65, and the uniformity coefficient is 2.322, as given in a table accompanying the above description. This sand weighs 2908 lb. per cu. yd.

Pioneer Sand Company, St. Joseph, Buchanan County.—This Company pumps the sand with a 6-inch centrifugal dredge pump, tows it to the plant on barges, and loads directly from barge to car with a 2-yard clam shell. Sand is also stock-piled and can be loaded from the pile to the car with the clam shell (Pl. XLIV, A). The only washing is that at the pump, the fine silt being carried out by the waste water from the barges. The product is passed over a 3-8 inch screen, the coarse waste going back into the river. The capacity of the plant is 300 yd. per day. The sand is used for plastering, brick laying, cement work, and engine sand. The plant has a spur of the St. Joseph Terminal Company. About one-half the output is shipped,

[1]Bull. U. S. Geol. Survey No. 331, pp. 43-44, 1908.

the chief points being Savannah, Maryville, Mound City, and other points north and east. Kansas City supplies the trade of the south.

Sample 169.—This sand passed over a 3-8 inch screen at the pump. As marketed, 3 per cent is retained on the 10-mesh, and 95 per cent on the 60-mesh sieve. The effective size is 0.25 mm. and the uniformity coefficient 1.8. The sp. gr. is 2.64, and the voids 37.8 per cent. The sand weighs 102.6 lb. per cu. ft., and 2771 lb. per cu. yd. Washing tests showed 0.45 per cent dirt. (See screen test tables, p. 224.)

Buchanan Sand and Supply Company, St. Joseph, Buchanan County.—This Company is the successor to the Contractor Sand Company. The sand it produces is pumped from Missouri River with an 8-inch centrifugal pump and towed on barges to the plant. At the plant is an inclined track which can be lowered onto the barge like a drawbridge. On this track runs a cable car operated by electricity (Pl. IX, B). The dump car is loaded by hand on the barge, and as it is hauled up the incline, dumps automatically on the stock pile. The only washing is through the pump, which allows the fine silt to flow off with the waste water. At the discharge, the sand passes over a ¼-inch mesh screen, the coarse gravel going back into the river. The capacity of the plant is 275 yards per day. By properly selecting the bars, coarse and fine sand can be obtained. The coarse sand is used for plastering, brickwork, and cement work, the fine, for asphalt work. The entire output goes to the local market.

Sample 170.—This sample, taken from the stock pile, represents the finer sand used in asphalt work. The entire sample passed the 10-mesh, and only 38 per cent is retained on the 60-mesh sieve. It is the finest sand tested from Missouri River. The effective size is 0.14 mm. and the uniformity coefficient 1.51. The sample has a sp. gr. of 2.64, voids 42.0 per cent, and the sand weighs 95.7 lb. per cu. ft., or 2584 lb. per cu. yd. Washing removed 1.10 per cent dirt. (See screen tests in table, p. 224.)

Sample 171.—This is a coarse sand from the same plant. At the barge it is passed over a ¼-inch screen. As marketed, about 5 per cent is retained on the 10-mesh and 97 per cent on the 60-mesh screen. The effective size is 0.27 mm. and the uniformity coefficient 1.72. The sand has a sp. gr. of 2.64, and the voids are 37.8 per cent. The weight is 102.6 lb. per cu. ft., or 2771 lb. per cu. yd. Washing removes 0.38 per cent dirt. (For complete screen tests, see table, p. 224.)

SCREEN TESTS O

No.	Passing each sieve and retained on the next.												Retained on No. 10	Total pa					
	200	150	100	90	80	70	60	50	40	30	20	10		200	150	100	90	80	70
150	0.63	0.27	3.17	5.26	3.32	8.86	11.76	16.27	10.86	13.66	14.37	6.88	4.69	0.63	0.90	4.07	9.33	12.65	21.
213	0.07	0.03	0.39	0.11	0.37	1.01	2.29	9.48	13.04	21.03	22.49	17.58	12.21	0.07	0.10	0.49	0.60	0.97	1.
155	—	—	—	—	—	—	0.25	0.31	1.24	7.93	27.47	37.92	24.88	—	—	—	—	—	—
154a	0.24	0.16	1.36	1.32	0.44	1.40	1.97	4.61	8.30	18.06	30.36	17.75	14.03	0.24	0.40	1.76	3.08	3.52	4.
159	0.15	0.05	0.56	1.02	0.40	1.70	3.30	8.60	11.70	19.40	21.70	17.00	14.20	0.15	0.20	0.76	1.78	2.18	3.
160	0.00	0.05	0.50	0.10	0.25	0.42	0.99	1.97	2.40	5.05	6.29	12.50	69.48	0.00	0.05	0.55	0.65	0.90	1.
162	—	—	—	—	0.10	0.10	0.15	0.50	1.55	8.50	40.25	40.55	8.30	—	—	—	—	0.10	0.
163	0.00	0.25	0.70	1.05	0.55	1.66	2.87	9.61	19.72	27.74	21.47	8.85	5.53	0.00	0.25	0.95	2.00	2.55	4.

SCREEN TESTS O

No.	Passing each sieve and retained on the next.												Retained on No. 10	Total passin					
	200	150	100	90	80	70	60	50	40	30	20	10		200	150	100	90	80	70
158	1.93	0.39	3.40	3.05	1.41	2.90	2.08	3.59	3.38	11.63	26.51	22.19	17.54	1.93	2.32	5.72	8.77	10.18	13.
182	0.15	0.11	0.82	0.96	0.45	1.66	3.70	12.45	16.08	14.00	21.15	20.11	8.36	0.15	0.26	1.08	2.04	2.49	4.
181	2.51	0.58	2.45	2.57	1.36	3.70	5.96	8.09	12.36	20.58	19.51	20.33	—	2.51	3.09	5.54	8.11	9.47	13.
164	0.66	0.29	1.02	0.71	0.47	1.38	3.23	13.38	24.14	25.35	16.51	10.76	2.10	0.66	0.95	1.97	2.68	3.15	4.
165	0.41	0.27	3.97	8.33	1.61	9.24	13.06	21.19	23.67	12.13	3.74	1.37	1.19	0.41	0.68	4.47	12.80	14.41	23.
169	0.00	0.35	0.33	0.33	0.24	0.90	2.17	11.95	25.90	27.83	15.40	11.30	3.30	0.00	0.35	0.68	1.01	1.25	2.
170	0.70	0.45	5.70	8.60	4.85	14.30	26.75	20.70	7.05	3.70	2.80	4.40	—	0.70	1.15	6.85	15.45	20.30	34.
171	0.00	0.20	0.30	0.30	0.20	0.60	1.60	7.90	24.90	32.40	17.10	9.60	4.90	0.00	0.20	0.50	0.80	1.00	1.

SCREEN TESTS ON COMPETING KAW AND

No.	Passing each sieve and retained on the next.												Retained on No. 10	Total pass					
	200	150	100	90	80	70	60	50	40	30	20	10		200	150	100	90	80	70
167	0.52	0.17	0.95	1.20	0.70	1.75	3.21	9.73	14.61	19.59	18.78	18.68	9.11	0.52	0.69	1.64	2.84	3.54	5.
168	0.00	0.13	0.23	0.45	0.24	0.83	1.46	5.10	9.85	16.40	22.21	43.10	—	0.00	0.13	0.36	0.81	1.05	1.
172	0.00	0.05	0.70	1.35	0.70	2.40	3.80	8.40	10.20	14.20	16.15	18.15	23.90	0.00	0.05	0.75	2.10	2.80	5.

MISSISSIPPI RIVER SANDS.

ing each sieve.						Effective size.	Uniformity coefficient.	Specific gravity.	Per cent voids.	Weight per cu. ft.	Weight per cu. yd.	Per cent dirt.	Locality.
60	50	40	30	20	10								
33.27	49.54	60.40	74.06	88.43	95.31	0.15	2.42	2.64	36.9	104.10	2811	0.36	Cape Girardeau.
4.27	13.75	26.79	47.82	70.31	87.89	0.26	2.46	2.65	37.1	104.30	2816	0.30	Crystal City.
0.25	0.56	1.80	9.73	37.20	75.12	0.51	2.40	2.63	35.6	105.80	2858	0.50	St. Louis.
6.89	11.50	19.80	37.86	68.22	85.97	0.26	2.77	2.635	36.5	104.60	2824	1.10	St. Louis.
7.18	15.78	27.48	46.88	68.58	85.58	0.28	2.70	2.64	38.3	101.80	2749	2.30	Hannibal.
2.31	4.28	6.68	11.73	18.02	30.52	0.49	7.75	2.635	27.8	118.70	3205	1.70	Hannibal, gravel screenings.
0.35	0.85	2.40	10.90	51.15	91.70	0.50	1.87	2.64	38.3	101.80	2749	0.38	Canton.
7.08	16.69	36.41	64.15	85.62	94.47	0.25	2.02	2.65	39.4	100.35	2709	0.50	Louisiana.

MISSOURI RIVER SANDS.

each sieve						Effective size.	Uniformity coefficient.	Specific gravity.	Per cent voids	Weight per cu. ft.	Weight per cu. yd.	Per cent dirt.	Locality.
60	50	40	30	20	10								
15.16	18.75	22.13	33.76	60.27	82.46	0.17	5.10	2.62	33.9	108.2	2922	2.80	St. Charles.
7.85	20.30	36.38	50.38	71.53	91.64	0.23	2.80	2.635	35.1	106.9	2886	0.75	Glasgow.
19.13	27.22	39.58	60.16	79.67	100.00	0.18	2.80	2.63	37.2	103.2	2787	2.80	Lexington.
7.76	21.14	45.28	70.63	87.14	97.90	0.23	1.90	2.63	38.5	101.9	2727	0.75	Kansas City.
36.71	57.90	81.57	93.70	97.44	98.81	0.15	2.00	2.64	40.5	98.2	2651	0.40	Kansas City.
4.32	16.27	42.17	70.00	85.40	96.70	0.25	1.80	2.64	37.8	102.6	2771	0.45	St. Joseph.
61.35	82.05	89.10	92.80	95.60	100.00	0.14	1.51	2.64	42.0	95.7	2584	1.10	St. Joseph.
3.20	11.10	36.00	68.40	85.50	95.10	0.27	1.72	2.64	37.8	102.6	2771	0.38	St. Joseph.

ATTE RIVER SANDS FOR COMPARISON.

each sieve.						Effective size.	Uniformity coefficient.	Specific gravity.	Per cent voids.	Weight per cu. ft.	Weight per cu. yd.	Per cent dirt.	Locality.
60	50	40	30	20	10								
8.50	18.23	32.84	52.43	72.21	90.89	0.23	2.47	2.62	38.2	101.2	2732	2.00	Kaw river, Kansas City.
3.34	8.44	18.29	36.69	56.90	100.00	0.30	3.20	2.63	35.0	106.8	2880	0.20	Kaw River, Kansas City.
9.00	17.40	27.60	41.80	57.95	76.10	0.23	4.00	2.62	33.5	108.9	2940	0.64	Platte River, near mouth.

STREAM SANDS AND GRAVELS FROM THE OZARKS.

Ozark streams during 1913 produced about 20 per cent of the State's output of sand and gravel, as practically all of them carry abundant sand and gravel deposits. For the most part, these are gravels with admixture of sand in varying proportions, but in a few places sands are secured with practically no pebbles. Where the upper reaches of the streams are entirely on the dolomite formations, all of the gravel is often flint, but down stream from outcrops of sandstone, especially of the Roubidoux, there is often a large admixture of quartz grains. By far the most common constituent among the coarser gravels is flint. In most of the streams, it makes the entire plus ¼-inch product, although in the Black River and other streams heading in the St. Francois Mountains, porphyry, trap, and granite are present in considerable quantities. The minus 30-mesh product is largely quartz, with flint as a minor constituent.

In the larger streams the gravels are usually very clean, but in the smaller streams they are often dirty to an extreme. These sands are frequently sharper than those of Mississippi or Missouri Rivers. Lignite is not found in them.

The Ozark streams yield gravels which are much less constant in their properties than are those of the large rivers already described. Dirt-tests on numerous samples gave results varying from the merest trace up to 4½ per cent. The effective size varies from 0.18 mm. to 0.54 mm. on the minus ¼-inch mesh product, and the uniformity coefficient from 1.60 to 13.11. From 0 to 68 per cent of the material passing the ¼-inch screen is retained on the 10-mesh and from 73 to 98 per cent on the 60-mesh screen. The sp. gr. varies from 2.49 to 2.63. This low figure is due to two causes: First, the chert itself normally has a lower mineral specific gravity than quartz; secondly, the chert is often partly leached and porous and carries air, which it is practically impossible to exhaust from the minute pores. Voids vary from 30 to 50 per cent. The weight varies between 80.3 lb. and 110.6 per cu. ft., lb. or between 2160 lb. and 2984 lb. per cu. yd. The chief gravel-producing streams of the Ozark region are Meramec River, Osage River, Black River, Joachim Creek, and Little Piney Creek. Many other rivers and creeks supply considerable material for local use. Most Ozark streams are capable of supplying a much larger quantity of gravel than is now being produced from them.

Meramec River.—This stream is by far the most important gravel producer of the Ozark region. During the year 1913, the Meramec produced 14 per cent of the value and 17 per cent of the weight of the entire sand and gravel output of the State.

Meramec sand and gravel consists entirely of flint and quartz, the plus 20-mesh product being exclusively flint. The finer product is quartz grains and small fragments of flint, varying in proportions from place to place. The minus 30-mesh is usually over half, and often nearly all, quartz. The material varies from subangular to sharp. In most places the sand is rather clean and free from silt, though of course care must be exercised in choosing dredging places. There is often a considerable admixture of tree-bark and fine twigs.

From the mouth of the Big Dry Fork near Meramec Springs to Valley Park extensive gravel bars of the best quality are abundant.

Meramec sand and gravel are in large demand in St. Louis and usually bring a better price on the market than the Mississippi product. The reason is said to be that it is coarser and sharper than the Mississippi sand.

Sand and gravel are being produced from the Meramec at Valley Park, Drake, Sherman, Pacific, and Moselle. Herewith follows a description of the plants operating on the river.

Continental Portland Cement Company, Syndicate Trust Building, St. Louis.—The plant of this Company is located at Valley Park, St. Louis County, on Meramec River (Pl. VIII, B). The gravel is pumped with a 14-inch centrifugal dredge pump, towed on barges by gasoline launch to the plant, and unloaded with a 2½-yard clam shell into a hopper, from which a belt conveyor carries it to the screening tower. A 6-inch screen over the intake keeps out the coarsest bowlders, and a 2½-inch inclined bar screen at the discharge carries all material larger than 2½ inches back into the river. The overflow from the barges washes out much of the mud.

At the tower, the gravel, together with a 4-inch stream of water runs by gravity over a series of steeply inclined stationary screens which separate the various grades, each of which runs into a hopper bin with chutes for loading the car. The waste water washes the silt and the finest sand back into the river.

The Company puts out the following standard grades of commercial gravel:

Concrete.—(2½ to 1½), used chiefly in foundations and heavy underground work.
Binder.—(1½ to ¼), suitable for reinforced concrete and overhead work.
Roofing.—(3-4 to ¼), used chiefly on tar roofs.
Torpedo.—(¼ to ⅛), especially suited for cement blocks, fence posts, asphalt streets, and surfacing of automobile roads.
Sand.—(1-8 and smaller) used mostly for brick laying, plastering, and cement work.

In addition to these, certain modified grades are produced, such as coarse and fine binder, coarse and fine roofing, and coarse and fine torpedo.

The Company has a spur of the St. Louis and San Francisco Railroad and one of the Missouri Pacific. Practically the entire output is used in St. Louis, St. Louis County, and East St. Louis.

Union Sand and Materials Company, International Life Building, St. Louis.—The plant of this Company is located at Drake, St. Louis County, on Meramec River. The Company also has sand plants at Hannibal, St. Louis, and Memphis, on Mississippi River. The Hannibal plant is described on p. 216 and the St. Louis plant on p. 215. The gravel is pumped from Meramec River by means of a 15-inch centrifugal dredge pump, is towed by steamer on barges (of which the Company runs four) to the plant, and is elevated to the screening tower by a clam shell and belt conveyor. A stream of water carried to the tower washes out the fine silt not already washed out during the pumping. Screening is done by means of stationary inclined screens, over which the gravel runs by gravity into loading hoppers, from which it can be drawn directly into the cars. A switch engine is constantly kept at the plant, as the capacity is about 40 cars per day. The company puts out the same standard grades of commercial gravel already described above, viz., sand, torpedo sand, roofing, binder, and concrete gravel. The plant has a spur of the Missouri Pacific Railroad. Much the greater part of the output goes to St. Louis and St. Louis County.

Sample 154-B.—This sample was sent by the Company and is their regular washed and screened sand. All of it had passed a 1-8-mesh screen before being received at this Bureau. Fourteen per cent was retained on the 10-mesh and 92 per cent on the 60-mesh sieves. The effective size is 0.24 mm. and the uniformity coefficient 2.81. The sp. gr. is 2.63, voids 39.0 per cent, and weight per cu. ft. 100.3 lb., or 2707 per cu. yd. Washing removed 0.7 per cent dirt. (See table, p. 242, for complete screen tests.)

Herewith is also given the result of a test of Drake sand by the Materials Laboratory of the U. S. Geol. Survey, located at St. Louis.[1]

"*Register No. Sd.22.*—A sand generously donated in large quantities by a St. Louis company is used at the laboratories wherever a standard sand is required in tests not involving the quality of the cement. The selection was influenced (1) by the physical quality of the sand and (2) by the facility with which it could be procured. It is designated Sd.22 and is a recent river sand, pumped by a suction dredge from the bed of Meramec River at Drake, Mo., about 15 miles from the laboratories. The dredge deposits the material in scows which convey it a few hundred yards to the screens where it is elevated by means of a clamshell bucket and washed down through a series of screens which separate the material into 2-inch, 1-inch, ½-inch, coarse, and fine sizes.

"The granularmetric analysis curve (fig. 11, p. 50, Bull. U. S. Geol. Survey No. 331) indicates that it lies midway between the coarse and the fine sand and that it is uniformly graded; 93 per cent passes the No. 10 sieve, 69 per cent passes the No. 20 sieve, 55 per cent passes the No. 30 sieve, and 17 per cent passes the No. 50 sieve. The percentage of voids is 36.4; the weight per cubic foot 98.8 pounds; there is only a trace of silt, and the yield in 1.3 mortar is 1.11."

According to accompanying tables, the sand has a sp. gr. of 2.60, and a uniformity coefficient of 2.700, and weighs 2668 lb. per cu. yd.

Meramec Portland Cement and Materials Company, Syndicate Trust Building, St. Louis.—This Company's plant is located at Sherman, St. Louis County, on Meramec River. The Company also has a sand plant, which has been described on p. 215, in St. Louis, on Mississippi River.

The sand and gravel is pumped from Meramec River by means of a 15-inch centrifugal dredge pump (Pl. V, B), a six-inch screen across the intake keeping out the coarser bowlders, logs, and debris. The barges are towed to the plant with drum and cable operated by the dredge engine, and unloaded by means of a 5-yard clam shell dipper. The material is dumped into a hopper, falls through on to a belt conveyor and is elevated to the screening tower (Pl. XI, A). Together with a stream of water, the sand and gravel is run by gravity over a series of steeply inclined screens, which separate it into the standard commercial grades. The waste water carries off what silt and very fine sand has not already been removed by the washing at the pump. From the screens the various grades run into hopper bins, from which the material is loaded onto the cars by chutes. The plant has a spur of the Missouri Pacific Railroad, and a switch engine is kept at the plant for handling the cars.

[1]Bull. U. S. Geol. Survey No. 331, p. 51, 1908.

A. Screening tower of Universal Sand Company, Pacific, Franklin County, on Meramec River.

B. Plant of J. H. Randles, Poplar Bluff, Butler County, on Black River.

The Company gets out the following standard grades of commercial gravel. The sizes vary somewhat from those given by other companies (cf. p. 227):

Ballast.—All material over 2 inches is run directly into cars from the screen, and given to the railroad for hauling it out of the way.

Concrete.—(1½ to 2), used largely for very heavy work, especially underground.

Binder.—(1 to 1 3-4), used chiefly for reinforced work.

Roofing.—(½ to 1), used chiefly on tar roofs.

Torpedo.—(¼ and smaller), especially suited for concrete blocks, fence posts, asphalt streets and automobile roads.

Sand.—(1-8 and smaller), used for plastering, brick work, and cement work.

A large proportion of the product is used in St. Louis and vicinity.

Universal Sand Company, Syndicate Trust Building, St. Louis.—The plant of this Company is located at Pacific, Franklin County, on Meramec River. The Company also has a sand plant, already described on p. 213, at Crystal City, on Mississippi River.

Gravel is dredged with a bucket from Meramec River by a dragline cable way, and hoisted directly to the screening tower (Pl. XLV, A). The sand is washed with a stream of water down over stationary inclined screens. The water washes out the silt and finest sand, the graded gravel falls into bins with chutes, and is loaded onto the cars by gravity. The capacity for washed and screened gravel is about 600 yards in 10 hours.

The Company also operates a 12-inch centrifugal dredge pump (Pl. XLIV, B), pumping ballast directly into the cars. The capacity of the ballast plant is about 30 cars daily.

The plant puts out ungraded gravel for ballast. Two grades of concrete gravel are handled, coarse (1½ to 1¼-inch), suited for heavy foundation work, and fine (1¼ to 5-8), corresponding nearly to standard binder, and used for reinforced and overhead work. In addition to the above, the Company grades special filter gravel and sand for filter beds. The grades are:

Sand
Fine gravel 3-16 to 3-8 inch
Medium gravel ¾ to 1 inch
Coarse gravel 1¼ to 1¾ inches.

These are arranged in filter beds in the order of their size. Sand is also produced for plastering, brick laying, and furnace construction.

The plant has a spur of the St. Louis and San Francisco

Railroad. The chief markets are St. Louis and the smaller towns along the St. Louis and San Francisco Railroad.

Sample 210.—This sand was taken from a pile being used in the construction of the new Rolla High School, Rolla, Mo. It was washed and screened through a 1-8-inch sieve. Of the sand as marketed, 15 per cent was retained on the 10-mesh and 96 per cent on the 60-mesh sieve. The effective size is 0.27 mm. and the uniformity coefficient 2.07. The sand has a specific gravity of 2.62 and shows 33½ per cent voids. It weighs 107 lb. per cu. ft., or 2889 lb. per cu. yd. Washing removed 0.17 per cent dirt. (For complete screen tests, see table, p. 242.)

Sample 208.—This is an unscreened and unwashed gravel, just as dredged with the drag-line. Only 40 per cent passed the ¼-inch mesh. Of these screenings, 64.7 per cent was retained on the 10 mesh, and 94 per cent on the 60-mesh screen. The effective size is 0.27 mm. and the uniformity coefficient lies between 8.00 and 13.00. The sp. gr. is 2.56 and the voids 30.8 per cent. The sand weighs 110.3 lb. per cu. ft., or about 2980 lb. per cu. yd. Washing removed 4½ per cent dirt, which included many twigs and pieces of wood. (See table, p. 242, for screen tests.)

Moselle and other Meramec sands.—The Materials Laboratory of the U. S. Geol. Survey at St. Louis tested certain Meramec sands and gravels, and the results of their tests are quoted herewith:

Sample Sd. 21.—This sample is a bar sand from Meramec River at Moselle, Mo.[1]

"According to the granularmetric analysis curve this is a very fine sand, 82 per cent passing the No. 30 sieve and 2 per cent passing the No. 80 sieve. A large amount of this sand, over 60 per cent, is of approximately one size, between Nos. 30 and 50 sieves. The percentage of voids is 40.9; the weight per cubic foot is 89 pounds; a trace only of silt is present, and the yield in 1.3 mortar is 1.05."

According to accompanying tables, the sp. gr. is 2.61, and the uniformity coefficient 1.706. The sand weighs 2406 lbs. per cu. yd.

"*Register No. Gl. 1*[2].—A sample obtained from a recent deposit of river gravel at the Morsches Spur Bar in Meramec River was designated Gl. 1. A dipper dredge was operated over a space 1200 feet long by 75 feet wide, transferring the material to scows or cars for delivery to St. Louis and other points. In handling the material by dredge no attempt was made to wash out the silt.

[1]Bull. U. S. Geol. Survey, No. 331, p. 51, 1908.
[2]Op. cit., p. 80.

"Only 42 per cent of the sample received at the laboratories passed the ¼-inch screen, and no portion of the screenings passed the No. 80 sieve. The screenings are very uniformly graded. There is practically no fine material (smaller than the No. 80 sieve). The percentage of voids is 29; the weight per cubic foot is 113.5 pounds; the amount of silt is 0.15 per cent."

According to accompanying tables, the specific gravity is 2.56.

"*Register No. Gl. 2*[1].—The sample designated Gl. 2 is a recent river gravel obtained from the Meramec River bar at Moselle, Mo. A clam-shell dredge operated over a space 4,000 feet long and 2,000 feet wide raised the material from the bottom of the river. The gravel is generally shipped to St. Louis, Mo.

"About 58 per cent of the samples received at the laboratories passed the ¼-inch screen. These screenings are not far from uniform in grading and contain but a small portion of fine material, only 3 per cent passing the No. 80 sieve. The percentage of voids is 31; the weight per cubic foot is 113.5 pounds; the amount of silt is 0.39 per cent."

According to accompanying tables, the specific gravity is 2.57.

Black River.—Gravels and sands from Black River are essentially chert and are very similar in composition and other properties to those from Meramec River, except that the former carry a considerable quantity of igneous material, especially among the coarser pebbles. These igneous pebbles consisting of porphyry, with smaller quantities of trap and granite, are derived from the pre-Cambrian rocks of the St. Francois Mountains and vicinity. Black River carries much excellent gravel. Descriptions of the plants operating on this stream follow.

Randels, J. H., Poplar Bluff, Butler County.—The Company operates a 6i-nch and a 4-inch centrifugal dredge pump. The material is towed by launch on barges from three to eight miles to the plant, lifted by endless bucket elevator to the screening tower (Pl. XLV, B), passed through a ½-inch mesh rotary screen, and dropped onto a belt conveyor which delivers to the cars. Much of the silt is washed out at the pumps by the overflow from the barges. The material gets no other washing.

The gravel is used for concrete work, and the sand for plastering, brick laying, and cement work. By proper selection of bars, coarser or finer grades of sand and gravel can be secured. About 80 per cent of the output is used in Poplar Bluff, and shipments have been made to nearby towns, especially to the southeast.

Sample 150-A.—All the material passed the ½-inch screen and only a very few pebbles are present which would fail to pass

[1]Loc. cit.

the ¼-inch mesh. As placed on the market, 17 per cent is retained on the 10-mesh and 94 per cent on the 60-mesh sieve. The effective size is 0.27 mm. and the uniformity coefficient 2.50. The sand has a sp. gr. of 2.58, and the voids constitute 39.6 per cent. The material weighs 97 lb. per cu. ft., or 2620 lb. per cu. yd. Washing removed 1.40 per cent dirt, much of which was bark and small sticks. (For detailed screen test, see table, p. 242.)

Turner, H., Poplar Bluff, Butler County.—The sand and gravel is pumped from Black River with a 6-inch centrifugal dredge pump, towed on barges an average distance of four miles, and loaded directly from the barges to wagons by hand. The only washing is through the pump, the overflow carrying off much of the finer silt. At the barge it is passed through a ¼-inch screen. The gravel is used for concrete, and the sand for paving sand, brick work, plastering, and cement work.

Murphy, W. J., Poplar Bluff, Butler County.—Mr. Murphy operates one barge. The sand and gravel is shovelled on to the barge by hand, towed to town, and shovelled from the barge to wagons for delivery. It is neither washed nor screened. By properly choosing the bars, both sand and gravel are produced. The output is used largely for plastering, brick work, and cement work.

Missouri Pacific Railroad, Mill Spring, Wayne County.—The railroad has run a spur across Black River, about half a mile from Mill Spring, and formerly had a clam shell which loaded directly from the gravel bar (Pl. XLVI, A), to the cars. A loading platform, with trap for loading cars with wheel scrapers and teams, was also installed. The output was used chiefly for ballast. Some of it, however, was used in railroad concrete work, and the agent reported small shipments for street work. The railroad paid S. L. Leeper, the owner, a royalty for the gravel. At the time the pit was visited, during the summer of 1914, there was none of the outfit left except the track and loading trap.

Sample 153.—This sample was taken directly from the bar and represents as nearly bar-run gravel as could be secured. The largest pebbles exceed 3 inches in size. Only 27 per cent of this sample passed the ¼-inch sieve. Of these screenings, 44.8 per cent was retained on the 10-mesh and 95 per cent on the 60-mesh sieve. The effective size is 0.31 mm. and the uniformity coefficient between 6.00 and 7.32. The sp. gr. is 2.53 and the voids constitute 30 per cent. The screenings have

a weight of 110.6 lb. per cu. ft., or 2984 lb. per cu. yd. Washing removed 2.30 per cent dirt. (See table, p. 242, for complete screen tests.)

Joachim Creek.—At present there is only one gravel plant in operation on this stream.

Harrison Bros. Gravel Company, Silica, Jefferson County.—The sand and gravel are secured from Joachim Creek with an 8-inch centrifugal dredge pump (Pl. IV, B) which pumps the material directly into a hopper, from which bucket elevators carry it to the car. The only washing is through the pump, the overflow carrying off the silt. A screen in the bottom of the sluice way of the hopper allows much of the fine sand to run out, giving a fairly clean gravel. Other than this the gravel is not graded. It is used in concrete work. The plant has a spur of the Iron Mountain Railroad, and the chief market is St. Louis.

Sample 154.—This sample, representing typical bar-run material, was collected directly from the bar. It carries pebbles up to an inch or more in size. The plus 20-mesh product is exclusively chert, and over half the minus 30-mesh is quartz sand. Of this sample 66.7 per cent passed the ¼-inch mesh. About 50 per cent of the screenings was retained on the 10-mesh, and 96 per cent on the 60-mesh sieve. The effective size is 0.33 mm. and the uniformity coefficient between 8.48 and 10.60. The sand has a sp. gr. of 2.53 and 36.5 per cent voids. The weight per cu. ft. is 100.4 lb., and per cu. yd. 2711 lb. Washing removed 2.40 per cent dirt. (See screen test tables, p. 242.)

Osage River.—Osage River carries abundant gravels, which are exclusively flint, while the finer sands have considerable quartz. The only company reporting a production from this river operates a plant at Osage City. There is also production from small tributaries of the Osage along the Rock Island Railroad, in Cole and Osage counties.

Osage River Gravel Company, Osage, Cole County.—This plant is located at Osage, Cole County, on the Osage River. The Company operates a dredge boat with endless chain and bucket system of dredging (Plates I, B and IV, A). Washing and screening are done on the boat. The gravel, together with a 4-inch stream of water, is first run into a 3-16-inch mesh cylindrical revolving screen. The water washes the silt and sand through the screen back into the river. From this screen, the gravel passes into a second revolving cylindrical screen of sheet

iron, with round holes about ¾ of an inch in diameter. The material coarser than this is run into the river, the good gravel goes onto a barge and is towed to the plant. The gravel is shovelled by hand from the barge into a wooden bucket, which is hoisted to the cars with power from a small engine. The capacity of the plant is about 125 yards per day.

Much of the recent output has gone to Jefferson City for use in the construction work of the new Capitol Building. Most of the former output has been roofing gravel, which has been shipped west to Kansas City, St. Joseph, Pueblo, Austin, and numerous other points.

Chicago, Rock Island and Pacific Railway.—From time to time this road has operated extensive gravel pits on tributaries of Osage River, in Cole and Osage counties. During the summer of 1914, operations were being carried on at Henley and Argyle.

Henley, Cole County.—Mr. Henley is loading ballast for the railroad. The gravel is shoveled into wagons by hand, hauled from Little Tavern Creek a distance from 1-8 to ¾-miles, and loaded on the cars through a trap, a bridge-like structure over the track, with a hole through which to dump the gravel. A small amount is used locally for concrete, but no commercial gravel is shipped.

Argyle, Osage County.—Mr. Sassen is loading gravel here for the Rock Island. The material is taken from a small tributary of Maries Creek. The gravel is shovelled into wagons by hand, hauled ¼ mile, and loaded onto the cars through a trap, as at Henley. The owners receive a royalty.

Sample No. 188.—This sample was taken from a loaded ballast car at Argyle. It contains pebbles up to 4 inches in diameter. The coarser material is entirely chert, and there is only a small percentage of quartz even in finer portions.

Only 28.8 per cent of this sample passed the ¼-inch screen. Of these screenings, 51 per cent was retained on the 10-mesh, and 98 per cent on the 60-mesh screen. The effective size is 0.41 mm., and the uniformity coefficient lies between 4.15 and 6.83. The screenings have a sp. gr. of 2.49, and 39.7 per cent voids. The material weighs 93.8 lb. per cu. ft. or 2531 lb. per cu. yd. Washing removed 3.9 per cent dirt, which was mostly present as a coating on the pebbles. (See screening tables, p. 242.)

Little Piney Creek.—Little Piney Creek in Phelps County carries extensive gravel and sand bars. The plus 20-mesh is almost exclusively chert, and the minus 30-mesh largely quartz,

derived from the Roubidoux sandstone. Two companies are operating on gravels from this stream. A description of these plants follow.

Freeman, J. H., Newburg, Phelps County.—Mr. Freeman leases a sand bar and a gravel bar, each lying between ¼ and ½-mile from the railroad, where he has a siding. The sand and gravel are loaded by hand, hauled with teams, and unloaded by hand. The gravel is neither washed nor screened. The sand is not washed, and the building sand is not screened.

Mr. Freeman has a plant for handling screened and dried engine sand (Pl. XII, A). The engine sand is screened by hand through an 8-mesh screen, shovelled into the dryers, and after being completely dried, is hauled by wheelbarrows into the cars. The outfit consist of seven Champion Sand Dryers, each with a capacity of 20 cubic feet of sand. Each dryer is a stove, about which there is a sheet iron jacket. The sand is shovelled into the top of the jacket and allowed to dry on an average of 50 minutes, and is then drawn off at the bottom. The length of time required to dry a charge depends on the humidity of the air and the dampness of the sand.

Mr. Freeman handles ballast, building gravel and sand, engine sand, and sand for bedding stock cars. His chief markets are the towns between St. James and Springfield along the St. Louis and San Francisco Railroad.

Sample 211.—This is a bar-run sample neither washed nor screened. About 6 per cent is retained on the 10-mesh and 89 per cent on the 60-mesh screen. The plus 20-mesh product is practically all chert, the minus 30-mesh product is very largely quartz. The effective size is 0.21 mm., the uniformity coefficient 1.85, sp. gr. 2.61, voids 48.9 per cent, weight per cu. ft. 80.3 lb., and per cu. yd. 2160 lb. Washing removed 0.20 per cent dirt. (See table of screen tests, p. 242.)

Pillman Bros., Arlington, Phelps County.—This plant is operating at the junction of the Little Piney and the Gasconade, but most of the gravel is furnished by the former. The bar is from 4 to 8 feet deep, 20 rods wide, and over a mile long. Formerly, the dredging was done with a cable drag-line, but at present the Company operates an 8-inch centrifugal dredge pump. A pontoon pipe line, buoyed up by barrel floats, carries the material from the pump to the end of the drag-line, where it again returns to the water and is carried with a 600-foot cable way to the loading tower by the drag-line bucket. A

3-inch bowlder screen rejects the coarsest material. The product is then washed down with a 3-inch stream over a ¼-inch inclined screen, giving two grades, gravel and sand.

Until recently the chief output has been ballast, but some structural material is shipped to points east and west along the St. Louis and San Francisco Railroad.

Other gravel bars (Pl. XLVI, B) occur along Little Piney Creek.

Gasconade River.—Much good gravel occurs along the Gasconade, but no plants are reporting production except Pillman Bros. at Arlington, and their product is washed in chiefly by Little Piney Creek. The actual dredging is from Piney.

Other producers.—A few scattering producers report an output from small streams, and they will be discussed together as unclassified.

Menefee, George T., and Sons, Sedalia, Pettis County.—This plant is located near Valda Station, Pettis County, on Spring Fork Creek, about 8 miles south of Sedalia.

Gravel is shovelled by hand from the bar to wagons, hauled a short distance with teams, run through a crusher to crush the coarser pebbles, and loaded into cars by gravity. Mr. Menefee has ordered a 2-inch pump, and will run a stream of water through the crusher to wash out the mud and fine sand. He also expects to put in screens and get out roofing gravel to ship to Kansas City. The gravel at present is used largely in concrete work in Sedalia. The plant has a spur of the Missouri Pacific Railroad, and shipments are made to Sedalia, Jefferson City, Boonville, and other nearby towns.

Sample 184.—This sample was secured from Mr. Menefee's stock pile in Sedalia, and represents the material as placed on the market. Only 17 per cent of the sample passed the ¼-inch screen. The entire plus 20-mesh product is flint, and very little quartz appears, even in the finer product. Of the screenings, 53 per cent is retained on the 10-mesh and 97 per cent on the 60-mesh sieve. The effective size is 0.38 mm. and the uniformity coefficient lies between 5.73 and 7.63. The screenings have a sp. gr. of 2.63, and show 34 per cent voids. The weight is 108.4 lb. per cu. ft., or 2927 lb. per cu. yd. Washing removed 3.4 per cent dirt. (See table of screen tests, p. 242.)

Strange, C. W.—Mr. Strange's bar is located on Little Gravois Creek on the Bagnell Branch of the Missouri Pacific at Bagnell, Miller County. The gravel is shovelled into wagons

A. Gravel bar at Mill Spring, Wayne County, Black River.

B. Gravel bar on Little Piney Creek, between Newburg and Arlington, Phelps County.

by hand, hauled a short distance to the train, and loaded by hand into cars. Mr. Strange was arranging to put in a loading trap and scraper when interviewed. The gravel is used for concrete work and is neither washed nor screened.

Sample 186-A.—This sample was sent to the office by Mr. Strange, and was reported bar-run, neither washed nor screened. Only 24 per cent of the sample submitted passed the ¼-inch mesh. Of these screenings, 96.8 per cent was retained on the 10-mesh, 2.83 per cent passed the 10-mesh and was retained on the 20, and only 0.37 per cent passed the 20-mesh screen. It is altogether probable that this sample was so selected as to avoid the finer material. The sp. gr. of the minus ¼-mesh product is 2.50, the voids 47.8 per cent, and the weight 82.0 lb. per cu. ft., or 2214 lb. per cu. yd. Washing showed only a trace of dirt.

Dunlap, John, Steelville, Crawford County.—Mr. Dunlap ships sand from Whittenberg Creek, a branch of Meramec River, about a mile east of Steelville, Crawford County. The sand is shovelled directly from the bars in the creek bed into the wagons, hauled about three-fourths of a mile, and shovelled into the cars by hand. It is screened through ¼-inch screens inclined over the wagon box to take out the coarse pebbles. The sand is not washed. The output is about 40 cars per year.

The entire output is used for foundry bed sand in the casting of pig iron, and is all shipped to Sligo, Mo.

Sample 193.—This sample was sent in by Mr. Dunlap and is reported to represent average bar-run sand, neither washed nor screened. It all passes the 10-mesh, and 73 per cent is retained on the 60-mesh screen. It has an effective size of 0.18 mm. and a uniformity coefficient of 1.60. The sp. gr. is 2.63, and the voids 43.2 per cent. The sand weighs 93.4 lb. per cu. ft., and 2521 lb. per cu. yd. Washing removed 0.50 per cent dirt. (See table of screen tests, p. 242.) The following is an analysis of this sand:

Analysis of creek sand from Steelville.

SiO_2	95.38
Al_2O_3	1.72
Fe_2O_3	0.88
CaO	0.16
MgO	0.23
Alkalies	1.13
Ignition	1.10
	100.60

Love Branch of the Little Dry Fork, Rolla, Phelps County.—This sample (No. 209) was taken from the gravel used in the construction of the new Rolla High School. Sixty per cent of the sample passed the ¼-inch screen. Of these screenings, 67 per cent is retained on the 10-mesh and 98 per cent on the 60-mesh sieve. The effective size is 0.54 mm. and the uniformity coefficient between 5.21 and 6.80. The screenings have a sp. gr. of 2.55, and 40 per cent voids. The weight per cu. ft. is 95.5 lb., or 2580 lb. per cu. yd. Washing removed 3.8 per cent dirt. (See screen test table, p. 242.)

STREAMS OF THE GLACIATED AREA OLDER THAN THE PENNSYLVANIAN.

This area, the gravels of which are somewhat similar to those of the Ozark region, comprises roughly the Counties of St. Charles, Lincoln, Pike, Ralls, eastern Monroe, Shelby, Marion, Knox, and Lewis. The formations are of Mississippian age, or older, and carry a great deal of chert. For that reason, as with the older formations of the Ozark area, there is much residual chert, and the stream gravels consist dominantly of chert pebbles. The drift in this eastern edge is mostly thin, possibly absent in places, and igneous pebbles make up but a small part of the gravel and sand.

Salt River.—Only one company reports gravel production from the streams of this area. This is on Salt River. Other streams in the region, however, carry a plentiful supply of good flint gravel.

Camery, George W., Hannibal.—This plant is located in Ralls County, about 8 miles southwest of Hannibal, where the St. Louis and Hannibal Railway crosses Salt River (Plates II, B; III, A; and III, B). The gravel is secured with a drag-line cable way, operating a 1½ yard bucket, over a distance of about 500 feet. The material is dumped into hoppers, and loaded by gravity into the cars. The gravel is neither washed nor screened. Practically the entire output is used by the St. Louis and Hannibal Railway. A small shipment of gravel, bar-run, was recently made to Bowling Green for structural work.

Sample 161.—This sample was collected from a loaded ballast car, and represents average unwashed, unscreened, bar-run gravel. Of the sample, 51.6 per cent passed the ¼-inch screen. Of these screenings about 21 per cent was retained on the 10-mesh, and 95 per cent on the 60-mesh screen. The

effective size is 0.28 mm. and the uniformity coefficient 2.35. The sp. gr. is 2.61, and there are 36.6 per cent voids. The sand weighs 103.4 lb. per cu. ft., or 2790 lb. per cu. yd. Washing removed 1.70 per cent dirt. (See screen test tables, p. 242.)

STREAMS OF THE GLACIATED PENNSYLVANIAN AREA.

This area lies to the west of the area already described in the previous section, or in other words, north of Missouri River, and west of Knox, Shelby, Ralls and Pike counties.

Since the underlying rock is chiefly Pennsylvanian, and since the Pennsylvanian formations on the whole carry very much less chert than the Mississippian and older formations, it follows that coarse chert and gravels are much less abundant in the area under discussion than in the Ozarks or in the northeastern part of the State.

In fact, this north central to northwest part of the State carries little or no coarse chert gravels. This area also carries a much heavier drift-sheet than does the area to the east, and hence derives a large part of its gravel from glacial material. The extreme western part of the area is in late maturity, and the streams carry little but fine sand and silt. The north central part of the State, toward the eastern edge of the area under discussion, is less maturely dissected, the streams have steeper gradients, and coarser sands and gravels are sometimes to be found in the creek beds.

Nodaway River.—The only river of this area from which a sand production is reported is the Nodaway, in Nodaway and Holt counties.

For the most part the sand of this stream is very fine-grained, but occasionally coarser bars occur. All of this sand is derived from the drift, and has much the same composition as the glacial bank sand described at Maryville and Guilford. It is somewhat cleaner than the bank sand.

A list of producers reporting Nodaway River sand follows.

Bodle, Wm.—The Bodle bar is located about a mile and a quarter west of Skidmore in Nodaway County. Mr. Bodle operates a 4-inch centrifugal dredge pump, pumping the sand directly into bins on the bank. There is no washing except through the pump, the overflow carrying out the fine silt. The sand is not screened. It is shoveled by hand from the bins to wagons, and hauled 1¼ miles to town. It is used chiefly for brick laying,

plastering, and cement work. The capacity is about 40 yards per day, and the entire output is used locally.

Sample 177.—This sample was taken from a pile of coarse sand near the pump. It is reported that such coarse sand is uncommon, the average product being much finer. Of this material, 46 per cent passed the ¼-inch sieve. Of these screenings, 26 per cent was retained on the 10-mesh, and 98 per cent on the 60-mesh sieve. The effective size is 0.36 mm., the uniformity coefficient 3.36, the sp. gr. 2.59, the voids 36.8 per cent, and the weight 102.4 lb. per cu. ft., or 2763 lb. per cu. yd. Washing removed 1.90 per cent dirt. (See screen test table, p. 242.)

Sample 178.—This sample was taken from the loading bin and was said to be an average sample. It all passed the 10-mesh, and 91 per cent was retained on the 60-mesh screen. The effective size is 0.23 mm., uniformity coefficient 1.94, sp. gr. 2.62, voids 41.9 per cent, weight per cu. ft. 95.1 lb., and weight per cu. yd. 2569 lb. Washing removed 1.2 per cent dirt. (See table of screen tests, p. 242.)

Carpenter, Fred.—This plant is located on the Nodaway River, about a mile from Maitland in Holt County. A small scow with several sand boxes, each holding ¼ of a yard of sand, is employed. A man with a long-handled dipper, shaped something like a funnel, dips the sand from the bottom of the river. When the boxes are full, the boat is poled or towed by hand to the landing, the boxes are hoisted to the bank by derrick and horse power and dumped on a stock pile. One man can dip from 6 to 8 yards a day by this method. The sand is used for plastering, cement work, and brick laying, and is all sold in the local market.

Sample 179.—This sample, taken from Mr. Carpenter's stock piles, is a coarse grade of sand, somewhat coarser than the average for this river. Of this sample, 29 per cent is retained on the 10-mesh, and 97 per cent on the 60-mesh screen. The effective size is 0.34 mm. and the uniformity coefficient 3.56. The sand has a sp. gr. of 2.615, and shows 50 per cent voids. The weight per cu. ft. is 81.7 lb., or 2206 lb. per cu. yd. Washing removed 1.70 per cent dirt. (See table of screen tests, p. 242.)

Sample 180.—This sample, also from Mr. Carpenter's stock pile, represents his average output. All of this sample passes the 10-mesh, and 91 per cent is retained on the 60-mesh screen. The effective size is 0.23 mm. and the uniformity coefficient 1.86. The sand has a sp. gr. of 2.63, 42.9 per cent voids and a weight of

93.8 lb. per cu. ft., or 2533 lb. per cu. yd. Washing removed 1.00 per cent dirt. (See screen test tables, p. 242.)

Roach, A.—Mr. Roach has an outfit similar to that operated by Mr. Carpenter, and it is located on Nodaway River, about 1-8 of a mile from Maitland, Holt County. He supplies sand of the same grade as that of the Carpenter plant to the local market.

Cole and Jester.—Cole and Jester operate a plant similar to the first two described. It is located about 1½ miles from Maitland on Nodaway River, in Holt County. The output is all used locally, largely by Nodaway and Holt counties for road building. A small amount of bedding sand is produced.

Mattox and Younger.—Mr. Mattox and Mr. Younger operate a plant similar to the others described at Maitland, Holt County, except that they have an inclined track and car by means of which the sand is raised from the water level to the bank above. Their entire output is used in the local market.

STREAMS OF THE UNGLACIATED PENNSYLVANIAN AREA.

This area includes the region immediately south of Missouri River, in the west part of the State, where the surface formations are of Pennsylvanian age. It practically comprises Saline, Lafayette, Jackson, Cass, Johnson, Henry, Bates, Vernon, and Barton Counties.

The non-cherty character of the Pennsylvanian formations precludes the abundance of chert gravels found in the Ozark area, or the glaciated area of rocks older than the Pennsylvanian. The absence of extensive drift, except possibly in the extreme north of the area, determines the lack of igneous and foreign materials. The streams are not rich in either sand or gravel, and no regular production is reported from that part of the State.

STREAMS OF THE UNGLACIATED MISSISSIPPIAN AREA.

This area includes the extreme southwestern part of the State, lying chiefly in Jasper, Newton, McDonald, Dade, Greene, Lawrence, and Barry counties, all outside what may properly be classed as the Ozark region. The most abundant surface rocks are highly cherty limestones of Mississippian age, and the chief gravels are chert gravels, with only very small admixtures of finer quartz sand.

Elk River.—Only one company has reported a regular

production from this area, for though gravel is abundant, it is forced to compete locally with chats, which are placed on the market in large quantities.

Carmichael Gravel Company, Noel.—(Successors to the Noel Gravel Company.) This company is operating about a mile north of Noel, McDonald County, on Elk River, known locally as Cow Skin River. The gravel is secured with a 10-inch centrifugal dredge pump, which discharges into a bin from which the gravel is raised by bucket elevator to the loading hopper, and thence by gravity into the cars.

At the time the plant was visited, the entire product was being disposed of to the Kansas City Southern Railway for ballast, and no screens were in operation. The company plans, however, to install a screening apparatus and get out roofing gravel. The capacity of the plant is 400 yards per day. The pump can discharge about 2 yards a minute. The plant formerly operated as a drag-line, but recently installed the pump.

Mr. Wilson of this Bureau took a carefully selected average sample from the bar. This sample had not been washed through the pump, and probably has a higher dirt content than the commercial product which has been pumped.

Sample 240.—Of this sample 91 per cent is retained on the ¼-inch screen. The coarse material is almost wholly flint pebbles up to 4 inches in diameter. There are a few flat pebbles of dark-gray to black fissile shale, which might prove harmful in a gravel to be subjected to great strain. Of the minus ¼-inch product, 62 per cent is retained on the 10-mesh and 95 per cent on the 60-mesh sieve. The sp. gr. is 2.42, the voids 38 per cent and the weight 101.8 lb. per cu. ft., or 2749 lb. per cu. yd. The effective size is 0.50 mm., and the uniformity coefficient between 3.00 and 7.00. Washing removed 7 per cent dirt from the screenings. There is very little sandstone in the rocks from which the gravels are derived, thus accounting for the very high percentage (91) of plus ¼-inch product. (See table of screen tests, p. 242.)

STREAMS OF THE SOUTHEAST LOWLAND.

A few small streams in the southeast lowland derive their gravels largely from Crowley's Ridge. The character of these sands and gravels is essentially the same as those given for the Tertiary material at Commerce (pp. 192-203). In fact, it is this material merely worked over again.

SCREEN TESTS ON SAND AN

No.	Passing each sieve and retained on the next.												Retained on No. 10	Total passing each sieve						
	200	150	100	90	80	70	60	50	40	30	20	10		200	150	100	90	80	70	60
154b	0.15	0.05	0.55	0.55	1.01	1.86	3.36	8.60	11.70	19.34	21.59	17.08	14.16	0.15	0.20	0.75	1.30	2.31	4.17	7.35
210	0.02	0.02	0.57	0.11	0.46	0.69	2.07	7.25	12.76	31.62	13.90	14.71	15.75	0.02	0.04	0.61	0.72	1.18	1.87	3.94
208	0.60	0.03	1.75	0.08	0.52	0.86	1.46	7.48	7.67	6.85	2.44	5.41	64.70	0.60	0.63	2.38	2.46	2.98	3.84	5.30
150a	0.31	0.10	0.52	0.73	0.45	1.46	2.01	5.32	9.65	22.32	26.42	13.78	16.93	0.31	0.41	0.93	1.66	2.11	3.57	5.58
153	0.40	0.10	1.00	0.10	0.40	0.60	1.90	4.50	5.10	12.10	10.40	18.60	44.80	0.40	0.50	1.50	1.60	2.00	2.60	4.50
154	1.09	0.04	1.21	0.04	0.27	0.47	1.05	2.73	6.42	14.20	7.58	15.47	49.50	1.09	1.13	2.34	2.38	2.65	3.12	4.17
188	0.26	0.06	0.53	0.06	0.13	0.26	0.66	1.85	3.57	9.55	10.97	20.78	51.30	0.26	0.32	0.85	0.91	1.04	1.30	1.96
211	0.26	0.38	1.28	0.22	0.99	1.63	6.27	23.00	23.00	32.02	3.33	1.83	6.38	0.26	0.64	1.92	2.14	3.13	4.76	11.03
184	0.05	0.05	0.34	0.10	0.29	0.48	1.15	3.03	4.47	9.25	7.80	19.30	53.80	0.05	0.10	0.44	0.54	0.83	1.31	2.46
193	0.60	0.09	1.33	3.74	1.47	7.92	11.03	29.46	29.91	10.39	2.80	1.26	—	0.60	0.69	2.02	5.76	7.23	15.15	26.18
209	0.16	0.01	0.31	0.01	0.14	0.18	0.58	1.60	2.22	3.82	4.40	18.58	67.80	0.16	0.17	0.48	0.49	0.63	0.81	1.39

SCREEN TESTS ON OTH

No.	Passing each sieve and retained on the next.												Retained on No. 10	Total passing e						
	200	150	100	90	80	70	60	50	40	30	20	10		200	150	100	90	80	70	60
161	0.32	0.11	0.95	0.11	0.42	0.85	1.91	5.72	9.95	24.45	23.00	11.33	20.78	0.32	0.43	1.38	1.49	1.91	2.76	4.67
177	0.08	0.01	0.30	0.07	0.12	0.30	0.90	3.60	8.00	17.80	18.20	23.90	26.80	0.08	0.09	0.39	0.46	0.58	0.88	1.78
178	0.00	0.32	0.44	0.72	0.63	1.77	4.30	13.15	22.51	25.50	15.69	14.91	—	0.00	0.32	0.76	1.48	2.11	3.68	8.18
179	0.00	0.00	0.34	0.15	0.18	0.45	1.20	4.05	6.33	13.60	19.80	24.60	29.30	0.00	0.00	0.34	0.49	0.67	1.12	2.32
180	1.82	0.13	0.44	0.52	0.44	1.44	3.63	13.40	22.80	35.45	16.05	3.88	—	1.82	1.95	2.39	2.91	3.35	4.79	8.42
197	0.80	0.07	0.70	0.13	0.40	0.53	0.80	8.23	9.12	18.61	18.10	15.90	26.20	0.80	0.87	1.57	1.70	2.10	2.63	3.43
198	0.00	0.24	0.25	0.56	0.40	1.51	3.63	13.82	27.53	31.93	13.17	4.84	2.12	0.00	0.24	0.49	1.05	1.45	2.96	6.59
240	2.50	0.70	0.70	0.17	0.35	0.35	0.35	0.70	1.07	2.50	10.00	18.60	62.20	2.50	3.20	3.90	4.07	4.42	4.77	5.12

AVEL FROM OZARK STREAMS.

	40	30	20	10	Effective size.	Uniformity coefficient.	Specific gravity.	Per cent voids.	Weight per cu. ft.	Weight per cu. yd.	Per cent dirt.	Per cent of total sample used (minus ¼-mesh).	Locality.
	27.83	47.17	68.76	85.84	0.24	2.81	2.63	39.0	100.3	2707	0.70	Total	Drake, Meramec river.
	23.95	55.57	69.47	84.18	0.27	2.07	2.62	33.5	107.0	2889	0.17	Total	Pacific, Meramec river.
	20.45	27.30	29.74	35.15	0.27	7.77-13.11	2.56	30.8	110.3	2980	4.50	— ¼ mesh = 40%	Pacific, Meramec river.
	20.55	42.87	69.29	83.07	0.27	2.50	2.58	39.6	97.0	2620	1.40	Total	Poplar Bluff, Black river.
	14.10	26.20	36.30	55.20	0.31	6.00—7.32	2.53	30.0	110.6	2984	2.30	— ¼ mesh = 27%	Mill Spring, Black river.
	13.32	27.52	35.10	50.47	0.33	8.48-10.60	2.53	36.5	100.4	2711	2.40	— ¼ mesh = 66%	Silica, Joachim creek.
	7.38	16.93	27.90	48.68	0.41	4.15—6.83	2.49	39.7	93.8	2531	3.90	— ¼ mesh = 29%	Argyle, Branch of Maries cr
	57.03	89.05	92.38	94.21	0.21	1.85	2.61	48.9	80.3	2160	0.20	Total	Newburg, Piney creek.
	9.96	19.21	27.01	46.31	0.38	5.73—7.63	2.63	34.0	108.4	2927	3.40	— ¼ mesh = 17%	Valda, Spring Fork creek.
	85.55	95.94	98.74	100.00	0.18	1.60	2.63	43.2	93.4	2521	0.50	Total	Steelville, Wittenberg branch.
	5.21	9.03	13.43	32.01	0.54	5.21—6.80	2.55	40.0	95.5	2580	3.80	— ¼ mesh = 60%	Rolla, Love branch.

TREAM SANDS AND GRAVELS.

re.	40	30	20	10	Effective size.	Uniformity coefficient.	Specific gravity.	Per cent voids.	Weight per cu. ft.	Weight per cu. yd.	Per cent dirt.	Per cent of total sample used (minus ¼ mesh).	Locality.
	20.34	44.79	67.79	79.20	0.28	2.35	2.61	36.6	103.4	2790	1.70	— ¼ mesh = 52%	Hannibal, Salt river.
	13.38	31.18	49.38	73.28	0.36	3.36	2.59	36.8	102.4	2763	1.90	— ¼ mesh = 46%	Skidmore, Nodaway river.
	43.90	69.40	85.09	100.00	0.23	1.94	2.62	41.9	95.1	2569	1.20	Total	Skidmore, Nodaway river.
	12.70	26.30	46.10	70.70	0.34	3.56	2.615	50.0	81.7	2206	1.70	Total	Maitland, Nodaway river.
	44.62	80.07	96.12	100.00	0.23	1.86	2.63	42.9	93.8	2533	1.00	Total	Maitland, Nodaway river.
	20.78	39.39	57.49	73.39	0.27	3.70	2.62	32.7	110.0	2970	2.20	— ¼ mesh = 46%	Dexter, Dexter creek.
	47.94	79.87	93.04	97.88	0.24	2.91	2.64	43.2	95.7	2584	1.00	Total	Dexter, Dexter creek.
	6.89	9.39	19.39	37.99	0.50	3.00—7.00	2.42	38.0	101.8	2749	7.00	— ¼ mesh = 9%	Noel, Elk river.

Map showing location of sand plants. See key, page 243.

Dexter Creek.—Only one producer of creek gravels reports from this area.

Norman, F. M.—This plant is located on Dexter Creek near Dexter, in Stoddard County. The material is secured by hand and hauled half a mile to the railroad. It is neither washed nor screened. By proper selection of bars, either sand or gravel can be produced. The product obtained is used chiefly for brick and stone laying, plastering, and concrete work. About one-half the output is used in Dexter, the remainder going chiefly to Sikeston and Charleston.

Sample 197.—This sand and the following sample were sent to this office by Mr. Norman. Of this sample 46 per cent passed the ¼-inch screen. The plus 10-mesh product is practically all flint pebbles of various colors from nearly white to dull black, and are well worn. The minus 20-mesh is about two-thirds quartz, and is sub-angular and somewhat coarser than the quartz sand found in the Ozark gravels, Of the screenings, 26 per cent was retained on the 10-mesh, and 96 per cent on the 60-mesh screen. The effective size is 0.27 and the uniformity coefficient 3.70. The sp. gr. is 2.62, and the voids 32.7 per cent. The screenings weigh 110 lb. per cu. ft., and 2970 lb. per cu. yd. Washing removed 2.20 per cent dirt. (See table of screen tests, p. 242.)

Sample 198.—About 2 per cent of this sample is retained on the 10-mesh, and 93 per cent on the 60-mesh sieve. The effective size is 0.24 mm., the coefficient of uniformity is 2.91, the sp. gr. 2.64, the voids 43.2 per cent, and the weight 95.7 lb. per cu. ft., or 2584 lb. per cu. yd. Washing removed 1.00 per cent dirt. (See table of screen tests, p. 242.)

LIST OF SAND AND GRAVEL PLANTS REPORTING PRODUCTION.

1. Pittsburgh Plate Glass Co., Crystal City.
2. Enterprise Sand and Mining Co., Herculaneum.
3. Silica White Sand Co., Festus.
4. Harrison Bros. Gravel Co., Silica.
5. H. B. Straight Filter Sand Plant, Crystal City.
6. Universal Sand Co., Crystal City.
7. Pacific Glass Sand Co., Pacific.
8. Tavern Rock Sand Co., Pacific.
9. Tavern Rock Sand Co., Pacific.
10. J. W. Glaser, Pacific.
11. Grays Summit White Sand Co., Grays Summit.
12. Tavern Rock Sand Co., Klondike.
13. Universal Sand and Gravel Co., Pacific.
14. St. Louis and San Francisco R. R. Ballast Pit, Wittenberg.
15. Morrison Ice and Fuel Co., Cape Girardeau.

SPINDLETOP ENGINEERING LIBRARY
LAMAR STATE COLLEGE OF TECHNOLOGY

16. J. Ellis, Commerce.
17. Pacific Cement Gravel Co., Pacific.
18. J. H. Randles Sand and Gravel Co., Poplar Bluff.
19. Henry Turner Co., Poplar Bluff.
20. W. J. Murphy, Poplar Bluff.
21. Mo. Pac. Ry. Co., Ballast Plant, Mill Spring.
22. Union Sand and Materials Co., St. Louis.
23. Meramec Portland Cement and Materials Co., St. Louis.
24. Meramec Portland Cement and Materials Co., Sherman.
25. Union Sand and Materials Co., Drake.
26. Continental Portland Cement Co., Valley Park.
27. John W. Allen and Son, South St. Louis.
28. Theo. Pundmann, St. Charles.
29. Union Sand and Materials Co., Hannibal.
30. G. W. Camery, Hannibal.
31. Canton Fuel Co., Canton.
32. Louisiana Sand and Gravel Co., Louisiana.
33. Stewart Peck Sand Co., Kansas City.
34. Pioneer Sand Co., St. Joseph.
35. Buchanan Sand and Supply Co., St. Joseph.
36. S. J. DeArmand, Maryville.
37. Phillips and Woodard, Maryville.
38. W. Thornhill, Maryville.
39. Henry Heitman, Maryville.
40. C. N. Stark, Maryville.
41. J. M. Hasty, Maryville.
42. J. Thompson, Guilford.
43. Wm. Bodle, Skidmore.
44. Fred Carpenter, Maitland.
45. Mattox and Younger, Maitland.
46. A. Roach, Maitland.
47. Cole and Jester, Maitland.
48. Lexington Triumph Press Brick Co., Lexington.
49. Glasgow Sand Co., Glasgow.
50. Mo. River Sand and Gravel Co., Boonville.
51. Chas. Donnivant, Boonville.
52. Will Mock, Boonville.
53. G. T. Menefee, Sedalia.
54. Jefferson City Sand and Gravel Co., Jefferson City.
55. Osage River Gravel Co., Osage City.
56. C. W. Strange, Bagnell.
57. Chicago, Rock Island and Pacific R. R. Ballast Pit, Henley.
58. Chicago, Rock Island and Pacific R. R. Ballast Pit, Argyle.
59. John Dunlap, Steelville.
60. J. H. Freeman, Newburg.
61. Pillman Bros., Arlington.
62. Scott County, Benton.
63. Glassstetler Pit, Benton.
64. M. J. Williams, Dexter.
65. F. M. Norman, Dexter.
66. G. W. Wetherholt, Campbell.
67. M. A. Dalton, Campbell.
68. City of Dexter, Dexter.
69. Carmichael Sand and Gravel Co., Noel.
70. American Silica Sand and Mining Company, Festus.

INDEX.

Page

Abandoned quarries.....151, 156, 160
Acid Rocks, weathering of chemically... 3
Acknowledgments.....XVI
Adair County, Pennsylvanian sandstone in..... 181
Aerial tram, for handling sand.....151, 163
to remove overburden, illustration of. 155
Aftonian (?), fauna of glacio-fluvial gravel..... 207
in table of formations..... 87
gravels, as a trade name..... 7
description of.....203-208
illustrations of.....204, 205, 207
Aggregate, see concrete aggregate.
Air bubbles, effect of in determining voids..... 24
Alkalies, determined for what purposes.. 30
in concrete aggregate..... 57
in moulding sands..30, 74, 75, 76, 209, 210
see also chemical analyses.
Allegheny River sands, method of washing described..... 41
Allen, John W., moulding sand pit of. 208-209
Allis-Chalmers crushers, referred to.... 40
Alton as a market for Missouri sand..50, 168
Alumina, binder in moulding sands....74, 76
content of St. Peter sands.....123-126
determined in analyses of sand..... 29
in sand for glass.....82, 83
removing by washing.....41-42
uses of sand for which a knowledge of is essential..... 30
see also chemical analyses.
Americus, St. Peter sandstone near.... 166
Amphiboles in sand, effect of on color... 8
Analyses, by whom made..... XV
chemical, see chemical analyses.
mechanical, see mechanical analyses.
Angularity, cause of in sands..... 17
see also sharpness, form of grain, shape of grain
Anticlines in the St. Peter area .....
.....115-116, 164, 166
see also folds.
Apple Creek, St. Peter sandstone near.....131, 134
Archaen of southeast Missouri, referred to..... 89
Arcola, mechanical analysis of Pennsylvanian sandstone..... 126
Area of glass sand deposits..... 83
Argillaceous sands, properties.....5, 19
see also clay.
Argyle, gravel from.....234, 242
Arkansas, market for Cape Girardeau sand..... 213
Tertiary quartzite in..... 191

Page

Arkose sand..... 3, 6
see also feldspathic sand.
Arlington, sand plant at.....35, 235-236
Armourdale, Kaw River sand from..... 223
Artificial binder in moulding sands....74, 77
Asphalt, pavements of.....66-69
Asphalt sand, defined..... 6
Missouri River sand use for..... 224
Asphaltic sandstone, accessibility of..183-184
bituminous content of.....68-69, 184, 185
description of.....181-189
geology of.....182-183
Higginsville deposit of.....186-188
location of..... 182
nature of the bitumen content of.... 185
physical character of.....185-186
Sheldon deposit of.....188-189
thickness of..... 183
value of deposits of..... 189
Asphaltine, amount present in so-called asphalt sand.....68-69, 185
Atchison County, glacial gravel in..... 207
Auglaize Creek, Roubidoux sandstone on 96
Augusta, St. Peter sandstone near..... 163
Auriferous sands, defined..... 6
Austin, Texas, market for Osage River gravel..... 234
Aux Vases Creek, Renault sandstone on. 180
Aux Vases sandstone, described.....178-179
chemical analysis of..... 179
mechanical analysis of..... 126
referred to.....88, 138
Ava, Roubidoux sandstone near.....99, 126
Bagnell, gravel plant at.....236-237
Bailey formation, described.....173-174
illustration of..... 174
in table of formations..... 88
see also Clear Creek (?) chert
Brainbridge formation, referred to...88, 172
Baker, O. I., cited on asphalt rock..... 66
on paving sand..... 65
on road gravel..... 69
on smoothness of gravel surfaces..... 61
Ball and Smith, cited on Gunter sandstone.....92, 93
cited on Roubidoux sandstone..... 96
Ballast, gravel for.....232-233, 234, 238
pit, Clear Creek (?) chert.....173-174
production by years..... 45
Bank sand and gravels, not angular.... 70
excessive clay in.....52, 55
for asphalt pavements..... 67
handled by hand.....31, 32
not properly graded in nature..... 59
percentage dirt in..... 10
see also Tertiary sands and Glacial sands.

Page
Barges, use of in sand production. 32, 35-38, 220-224, 226-229, 231-232
illustrations of. 37, 38, 39, 213, 215, 220, 222
see also Mississippi, Meramec, Missouri River, etc.
Bark Creek, St. Peter sandstone along. . 141
Barry County, asphaltic sandstone in. 182, 184
gravel supply in. 241
Tertiary gravel in. 189
Bar sand and gravel, not properly graded in nature. 59
handled by hand. 31
see also Meramec River, Black River, Missouri, etc.
Bars, gravel, illustrations. 236
see also Meramec River, Black River, etc.
Barton County, asphaltic sandstone in. 181, 182, 183
gravel supply in. 241
Basic rocks, weathering of, chemical. . . . 3
Bates County, asphaltic sandstone in. 181. 182
gravel supply in. 241
Beauvais sandstone, description of 88, 174-175
suitable for glass sand. 175
Bear Creek, Roubidoux sandstone on. . . 99
Beaver Creek, Roubidoux sandstone on. 99
Becker, St. Peter sandstone near. . . . . XIV, 156, 157, 160
Bedding, in Clear Creek (?) chert. 174
in Everton sandstone. 103-104, 139
illustration. 44
in St. Peter sandstone. 117, 162
of formations, see also formation in question
Bedding sand. 86, 217, 222
Bedsworth, N. W., sand pit of. 170
Belleville as a market for Missouri sand. 50
Belt bucket dredge, see bucket dredge.
Belt conveyors. 38, 215, 217, 226, 227, 231, 232
illustrations of. 40, 215
see also endless belt conveyor.
Benton, gravel pits near. 71, 199-200, 201, 206
gravel pits, illustration of. 194
sand handled by hand at. 31
Benton County, Gunter sandstone in. . . 92
Tertiary gravel in. 189
Benton Hills referred to. 191, 195, 199
Bermuda calcareous sand, referred to. . . 5
Bernie, Tertiary gravel near. 200
Bethany Falls formation in table of formations. 80
Biehle, St. Peter sandstone near. 102, 110, 134
Big Dry Fork referred to. 226
Big River, St. Peter sandstone along 141, 142, 151
escarpment along. 119
Everton sandstone. 101
Big Spring, Perry County, St. Peter sandstone near. 122, 136
Big Tavern Creek, Roubidoux sandstone on. 96

Page
Binder Gravel, size defined. 7, 227, 229
Binder, in fire and furnace sand. 85
in gravel for road surfacing. 70-71
in moulding sands. 74, 76, 77
Bins, storage and drying, for glass sand. 44
Birdseye formation, in table of formations. 88
Bituminous matter, amount in natural sands. 68-69
Bituminous sand, defined. 6
sandstone, description of. 181-189
Black River formation, in table of formations. 88
Black River, gravel and sand production. 32, 33, 34, 35, 44, 47, 225, 229, 231, 233, 236, 242
uses of. 231-232
"Black sands" defined. 6
Blasting, in sand quarries. 39
Bloomfield, Tertiary gravel near. 201
Bloomsdale, escarpment near. 119
Everton sandstone near. 102, 104, 107
St. Peter sandstone near. 138, 140
"Blowing" during casting. 75
Board of Managers. II
Boarman School, Beauvais sandstone near. 175
Boat dredge, illustration of. 32, 36, 37, 213, 220, 222, 223
on Osage River. 233-235
see also centrifugal pump
Boat, sand dipped from. 33
Bodle, Wm., gravel business of. 239-240
Bois Brule Creek, St. Peter sandstone along. 114
Bois River, Aux Vases formation along. . . 178
Bolin Creek sandstone, described. 96
referred to. 89, 93, 94
Bollinger County, St. Peter sandstone in. 106, 126, 134
map of. 134
Bond, see binder.
Boone County, St. Peter sandstone doubtfully present in. 107
Boone formation referred to. 88, 178
Boone residuum for road surfacing. 70
Bonneterre formation, referred to. 89, 91
Boonville, market for Valda gravel. . . . 36
sand plant at. . 32, 37, 43, 47, 219, 220-221
illustration of. 38
Bourbeuse River, Pennsylvanian sandstone near. 180
Bowlder clay. 203, 204, 205
see also till.
Bowling Green, market for gravel. . . 218, 238
Box hoist, described. 39
illustration of. 41
Branson, E. B., cited on Devonian sandstone. 175
on sandstone at Holt Summit. 170
Brass sand, defined. 76
Brewerville (Brewer), Everton sandstone near. 102, 103
St. Peter sandstone near. . . . . XIV, XV, 112, 115, 134, 135

Page

Bricklaying, sand suited for..... 53
Brick, sand-lime, sand for..... 64
Bridges, concrete construction of..... 62
Broadhead, G. C., cited on asphaltic sandstone.....182, 183, 185
on Roubidoux sandstone..... 97
on St. Peter sandstone.....164-165
on Vermicular sandstone..... 176
Brown color in sand, what due to..... 8
Brown, J. S., cited on Everton sandstone..... 101
on thickness of St. Peter..... 142
Bush Creek, St. Peter sandstone along.. 158
Bubbles of air, effect in determining voids..... 24
Buchanan County, Missouri River sand from.....223-224
sand plants in, illustrations of..39, 41, 223
Buchanan Sand and Supply Company, Missouri River sand plant.....38, 224
illustration of..... 41
Bucket dredge, Osage River.....35, 233-234
illustration of.....32, 36
Bucket elevator on Elk River..... 242
Buckley, E. R., city of asphaltic sandstone.....184, 188, 189
on clay in pavement foundations.... 65
on Devonian sandstone..... 175
on grading in pavement sand..... 66
on granite residual..... 89
on hardpan gravel..... 211
on Pennsylvanian sandstone..... 180
on public roads..... 64
on road gravels.....69-71
on sidewalk specifications..... 63
on Tertiary..... 190
Building sand, described.....51-64
Burchard, E. F., cited on composition of slimes..... 42
on properties of glass sand....80, 81, 83-84
on St. Peter sandstone.....132, 136, 169
Bureau of soils, see Soil Survey.
Bureau of Standards, cited on form of grain for plaster, etc..... 17
on organic matter, sulphides, etc. in concrete aggregate.....30, 57
on sharpness of sand..... 53
cited on size of grain for plaster, etc..14, 58
test of Commerce gravel by...61, 194-198
Burlington formation, referred to....88, 178
Burlington residuum for road surfacing. 70
Burlington, see Chicago, Burlington & Quincy Railroad.
"Burning out" of moulding sands..... 75-76
Bushel, as unit of sand marketing.... 46-47
Butler County, sand and gravel from... .....231, 232, 242
sand plant in, illustration of..... 229
Buttram, Frank, cited on properties of glass sand..... 81
Byng, J. C., engine sand, deposit of.... 99
Byrd's Creek, St. Peter sandstone near.. 131
Byrnesville, escarpment near..... 119
St. Peter sandstone near.....XVI, 141
Cable drag-line, use of in sand industry.. .....34-35, 229, 235-236, 238-239
illustrations of.....34, 35, 229

Page

Cain Creek, St. Peter sandstone near... 131
Calcareous marl, effect of on concrete... 11
Calcareous sands, defined..... 5
Calcite, as a flux..... 30
in sands.....19, 29, 133
Calcium, see chemical analyses.
Caldwell County, asphaltic sandstone in. 182
Caledonia, Lamotte sandstone at..... 90
Calhoun County, Illinois, St. Peter sandstone in..... 115
Calhoun formation, in table of formations..... 87
California, market for Missouri River sand..... 220
Call, R. E., cited on Tertiary quartzite.. 191
Callaway County, Devonian sandstone in..... 175
St. Peter sandstone in.....107, 170
map of..... 166
Callaway formation, in table of formation..... 88
Cambrian, referred to.....89, 127
Camden County, granite in..... 89
Gunter sandstone in..... 93
Camery, G. W., gravel plant of.....238-239
illustrations of.....34, 35
Campbell, sand handled by hand at.... 31
Tertiary gravel near.....71, 200
Caney as a market for Missouri sand... 50
Canton Fuel Company's plant, description of.....217-218
illustrations of.....37, 216
Canton, sand plant at.....
.....36, 37, 47, 213, 215, 126, 217-218
Cap au Gres fault.....
.....107, 115, 116-117, 130, 167, 168
Cap au Gres sandstone, same as St. Peter.
Cape Cinque Hommes Creek, St. Peter sandstone along.....114, 135, 136
Cape Girardeau and Northern Railroad, St. Peter sandstone along.....
.....102, 110, 132, 136, 137
Cape Girardeau City, Mississippi river sand from.....38, 213
St. Peter sandstone near.....113, 115, 132
Cape Girardeau County, Everton, relation of to St. Peter.....111-112
Everton sandstone in.....102, 103
ferruginous sand in..... 129
gravel pit at Daisy.....70, 21
Jefferson City-St. Peter contract in.. 110
Joachim sandstone in.....126, 171
Joachim-St. Peter contract in..... 108
Roubidoux, sandstone in, described.. 100
St. Peter sandstone, chemical analyses of.....122, 123-124, 132, 133
description of.....31-134
illustration of..... 133
map of..... 131
mechanical analysis of..... 126
referred to.....
..XIV, 49, 106, 113, 114, 117, 120, 134
Thebes sandstone in..... 172
Cape Girardeau formation in table of formations..... 88
limestone, referred to..... 172
sandstone described..... 172

Page

Carbonates, in sand for asphalt pavements ... 67
limit of in filter sands and gravels ... 79, 80
often present in sands ... 29
Carboniferous chert in Tertiary gravel ... 189
Carboniferous period, referred to ... 180
Carboniferous sandstone, referred to ... 170
see also Pennsylvanian, Aux Vases, Chester, Renault, Vermicular, etc.
Carmichael Gravel Company, gravel from ... 242
Carondelet, moulding sand at ... 208-209
moulding sand at, illustrations of ... 208
Carpenter, Fred., gravel business of ... 240-241
Carroll County, asphaltic sandstone in ... 182
Pennsylvanian sandstone in ... 181
Carthage, test of asphaltic sandstone in ... 189
Case hardening in St. Peter sandstone ... 130
Cass County, asphaltic sandstone in ... 182
gravel supply in ... 241
Cedar County, asphaltic sandstone in ... 182
Pennsylvanian sandstone in ... 181
Vermicular sandstone in ... 176
Cedar Hill, Everton sandstone near ... 101
Cementation, of Everton sandstone ... 105
of St. Peter sandstone ... 39, 40, 130, 131, 142, 147, 149, 153, 157, 158, 159, 161, 164, 166, 167, 168
see formation in question, also hardness, friability, etc.
Cementing power of Lafayette (?) gravels for road surfacing ... 71
Centrifugal pump dredge, effect on cleanness of sand ... 10
effect on coarseness of sand ... 13-14
illustrations of ... 36, 37, 213, 220, 222, 223
where used in sand production ... 35-36, 212-218, 219-224, 226-233, 235-236, 239-240, 242
see also dredge, boat, Mississippi, Missouri, etc.
Ceramic industry, silica for ... 173-174
Champion sand dryers, described ... 235
illustration of ... 44
Chanute formation in table of formations ... 88
Charette Creek, St. Peter sandstone along ... 164, 165
Chariton River, glacial gravel along ... 207
Charleroi, Pa., glass plant at ... 144
Charleston, market for Dexter gravel at ... 243
Chats, as railroad ballast, referred to ... 72
Chattanooga shale, referred to ... 88, 175
Chauvenet, analysis by ... 169
see also Regis Chauvenet & Company.
Chemical analyses, as a guide to refractoriness ... 74, 75
asphaltic sandstone, Missouri ... 184-185, 187, 189
Aux Vases sandstone ... 179
Commerce sandstone ... 192
Everton sandstone, Ste. Genevieve County ... 122, 140
glass sand (see also St. Peter) ... 81, 121-126
Lamotte sandstone ... 90
Mississippi River sands ... 212
Missouri River sands ... 219

Page

Chemical analsyes—
moulding sands from Herculaneum ... 210
from St. Louis ... 209
from Steelville ... 237
ideal ... 76
Oklahoma asphaltic sands ... 68
Portland cement used in tests of Commerce gravel ... 195
sandstone from Sedalia ... 171
St. Peter sandstone, average of ... 121
Cape Girardeau County ... 122, 123, 124, 132, 133
comparison of washed and unwashed ... 42
Crystal City ... 41, 42, 122-126, 128
Franklin County ... 122, 158, 160
from other states ... 125
Holt Summit ... 170
Jefferson County ... 122, 144, 150, 151
Lincoln County ... 122, 168, 169
Montgomery County ... 122, 166, 167
Perry County ... 122, 136, 137
previously published ... 123
St. Charles County ... 122, 162
Ste. Genevieve County ... 122, 140
St. Louis County ... 122, 153, 155
slime from washing of ... 42
summary ... 121-126
Warren County ... 122, 165
Steeleville, creek sand from ... 237
Tertiary find sand, Commerce ... 199
Thebes sandstone ... 172
value of ... 29-30
Chemical composition, sands, general discussion of ... 29-30
of St. Peter sandstone ... 121-126
see also chemical analyses.
Chemical weathering, in the formation of sand ... 3-4
Cherokee formation, referred to ... 88, 181, 182, 183, 188
Cherryvale formation, in table of formations ... 88
Chert, at Jefferson City-St. Peter contract ... 109-110
Clear Creek (?) described ... 173-174
deposit at Wittenberg, Perry county, illustration of ... 174
for road surfacing ... 69, 71
gravels, of Ozark Region ... 225-238
residual ... 4
Salt River ... 238-239
smoothness of surfaces of ... 61
Tertiary ... 89-203
see also gravel pits, gravel, dredging, Black River, Joachim Creek, etc.
in glacial gravels ... 203, 205, 206, 207
in Mississippi River sands ... 211
in Missouri River sands ... 218
in sands, effect on specific gravity ... 18, 225
Chester quadrangle, as a base map for work ... XV
Chester sandstone, mechanical analysis of ... 126
Cheyenne, Wyoming, market for filter sand ... 214

Page
Chicago & Alton Railroad, asphaltic sandstone along ... 187
glass sand on ... 170
Chicago, Burlington & Quincy Railroad, sand and gravel plants on ... 217-218
Chicago, Rock Island & Pacific Railroad, glass sand on ... 160
gravel plants on ... 32, 233-234
Chlorite, as a coloring matter in sand ... 125, 128
Chouteau sandstone referred to ... 88, 176, 177
Cinders as railroad ballast, referred to ... 72
Clam shell dredge, used in sand industry ... 34, 37-38, 215-216, 220-223, 226-232
illustrations of ... 38, 39, 40, 213, 215, 216, 220, 222, 223
Clark County, glacial gravel in ... 207
Clarks Creek, Roubidoux sandstone on ... 99
Classification of sand ... 5-8
Clay, as binder in gravel for road surfacing ... 70-71
as binder in moulding sands ... 74, 76
films, harmful in sand ... 11, 51, 52, 53, 55-57, 66
see also glacial gravels and Tertiary gravels.
for railroad ballast, referred to ... 72
harmfulness in sand ... 41
in bedding sand ... 86
in concrete aggregate ... 10-11, 54, 55-57
in Everton sandstone ... 104
in filter sands and gravels ... 79, 80
in glacial gravels, see gravel pits, dirt content, glacial gravel.
in glass sand ... 81, 82, 83
in railroad ballast ... 72
in sand, as an impurity ... 5, 9-11, 41
in sand for sand lime brick ... 64
in sand, not harmful in small quantities for structural purposes ... 51, 52
in Tertiary gravels, see gravel pits, dirt, content, Tertiary gravels.
layers, rejection of ... 45
little altered by weathering ... 3
removed by washing ... 41-42
water proofing, effect of ... 52, 62
Clay County, glacial gravels in ... 207
Pennsylvanian sandstone in ... 181
Clayton, Iowa, analysis of St. Peter sand from ... 125
Cleanness, in concrete aggregate ... 54, 55-57
in filter sands and gravels ... 79
in gravel for railroad ballast ... 72
in moulding sands ... 76
in sand for asphalt pavements ... 66, 67
in sand for bricklaying ... 53
in sand for plastering ... 51-52
in sand for stone masonry ... 54
of sand, discussed ... 9-11
see also clay, dirt and silt.
Clear Creek (?) chert, described ... 73-174
illustration of ... 174
Clear Creek formation, in table of formations ... 88
"Clear Creek" member of Cherokee, referred to ... 181

Page
Clement, St. Peter sandstone near ... 140
Cliffdale Hollow, natural bridge in ... 119
Clifton, sandstone near ... 170, 171
"Clinching" of plaster, failure due to fine sand ... 52
Coal, effect of on concrete ... 11
in Pennsylvanian sandstone ... 180
Coarseness, effect of transportation on ... 4
for engine sand ... 77-78
for sand-blast sand ... 85
see also size of grain.
Coarse sand, defined ... 7
desirable for concrete work ... 16
Coeffcient of uniformity, mechanical analyses, and uniformity coefficient.
Coffeyville, as a market for Missouri sand ... 50
Cohesiveness, in moulding sands ... 74
Coal and Jester, gravel business of ... 241
Cole Camp Creek, Gunter sandstone on ... 92
Cole Camp sandstone, same as Gunter ... 92-93
Cole County, gravel plant in ... 233-234
gravel plant, illustration of ... 32, 36, 41
Roubidoux sandstone described ... 98
sand plant in ... 220
illustration of ... 220
Colorado as a market for Missouri sand ... 47, 243
Color, as an indicator of purity in sand ... 121
in Everton sandstone ... 104
in St. Peter sandstone ... 128-130
in sand for bricklaying, plastering and stone masonry ... 53, 54
of formations, see formation in question of sand, discussed ... 8
relation to chemical content ... 5
Columbia, market for Missouri River sand ... 221
Commerce, Commerce sandstone at ... 125, 191-192
gravel pit at, illustration of ... 194
sand handled by hand at ... 31
Tertiary gravel and sand at ... 11, 192, 193-199, 201, 206, 242
Commerce sandstone, chemical analysis of ... 192
description of ... 191-192
mechanical analysis of ... 126
Commercial grades, Meramec gravel 226-229
Committee on ballasting, cited on ballast specifications ... 72-73
on concrete and reinforced concrete, cited on gravel specifications ... 57
Comparison of glass sand, analyses of washed and unwashed ... 41-42
Competition from points outside the state ... 48-49
Composition, of St. Peter sandstone ... 121-126
of sand asphalt pavements ... 66-69
see also chemical analyses.
Compressed air in drilling ... 39, 146, 148, 154, 163
Compressive strength of concrete made with Commerce sand ... 197
Concordia, Phelps sandstone near ... 177

Page
Concrete aggregate, properties desirable in....54-62
properties of used in Portland cement tests of Commerce gravel.... 195
Concrete, effect of calcareous marl on... 11
effect of clay on strength of....10-11
effect of humus on strength of.... 11
effect of peat on strength of.... 11
for pavement foundation.... 65
Concrete gravel, glacial gravel for...204-208
referred to in classification.... 8
size defined....7, 227, 229
Tertiary gravels, suited for.... 203
see also gravel, Meramec River, Tertiary, etc.
Concrete sand, chemical composition essential for.... 30
Concrete, tests on, from Commerce gravel....194-198
uses to which put....62-63
Conditions of the sand trade....45-50
Condra, G. E., cited on coarseness desirable in mortar sand....16, 52
on effective size.... 15
on engine sand.... 77
on properties of plastering sand....51, 52
on sand-lime brick.... 64
on sand sizes.... 7
on uniformity coefficient.... 14
Conglomerate, basal, Everton.... 143
basal St. Peter.102, 110-112, 127, 128, 134
in the Lamotte....89-91
in the pre-Cambrian.... 89
in the Phelps sandstone.... 177
Consolidated formations, securing sand from.... 39
Contract, Joachim-St. Peter, see Joachim-St. Peter contract.
Jefferson City-St. Peter, see Jefferson City-St. Peter contract.
Contents, table of....III-IX
Continental Portland Cement Company, gravel plant of.... 226
illustration of.... 40
Contractor Sand Company referred to.. 224
Coons, A. T., cited on sand lime brick... 64
Cooper County, sand plant in....220-221
sand plant in, illustration of.... 38
sandstone in....70, 171
Vermicular sandstone in.... 176
Coral sand, defined.... 6
Core sand, contrasted with sands for moulds.... 74
Mississippi River sand used for.... 77
Missouri River sand used for....77, 222
St. Peter sandstone used for.... ....50, 77, 148, 149, 155, 160, 163
referred to in classification.... 8
Cost data, on sand handling....47, 48
on screening and washing ballast.... 73
on washing lignite out of sand.... 41
Cost, see also prices.
Cotter formation, referred to....89, 101
County descriptions, see name of county desired.
Cow Skin River, gravel from.... 242
Page
Crane, for handling clam shell, described. 37
for handling clam shell, illustrations of....39, 41, 220, 223
Crane, G. W., cited on St. Peter sandstone....110, 111, 112, 116, 118, 161, 164, 165, 166
mapping by....XIV
Crawford County, Roubidoux in, described.... 100
sand shipped from....237, 242
Creek sands and gravels, description of 211-244
Creighton, Pa., laboratories of Pittsburg Plate Glass Co....83, 144
Cretaceous (?), Commerce sandstone of. 191
Cross bedding, in Bolin Creek sandstone. 96
in Everton sandstone....103-104
in glacial gravels....203, 205, 206
illustrations of....204, 205, 207
in Gunter sandstone.... 92
in Lafayette (?) gravel.... 190
in Roubidoux sandstone....94, 98
in St. Peter sandstone....109, 118
illustration of.... 109
in Tertiary gravels.... 194
see also formation in question.
Crowley's Ridge, sand and gravel.... ....192-203. 242
sand and gravel, illustrations of.... 194
sands, excessive clay in....55, 56
Tertiary quartzite in.... 191
Crushed rock, as railroad ballast, referred to.... 72
Crushed gravel.... 236
Crushed sandstone, for screen tests.... 13
methods of.... ...40, 146-147, 154, 156, 158, 160, 163
Crystal City, escarpment near.... 119
Everton sandstone near.... 104
glass sand plant at, illustrations.... ....42, 133, 145
Mississippi River, sand from.... ....36, 40, 47, 78, 80, 213-215, 229
sand plant on illustrations of....43, 213
moulding sand from.... 77
quadrangle, as a base map for work.. XV
St. Peter escarpment near, illustrations.... 109
St. Peter sandstone, analyses of.... ....41-42, 122, 123,124, 125, 126
near.... ....XV, 49, 107, 112, 115, 128, 130, 141, 142, 143, 144, 145, 146, 150, 151, 164
screen tests of.... 126
tunnels operated at.... 40
washing sand, referred to.... 40
Crystal City sandstone, same as St. Peter.
Crystal form in sands.... 17
Cuba, Roubidoux sandstone near.... 100
Culverts, concrete construction of.... 62
Cummer dryer, at the glass and plants... 147
Curbs, concrete construction of.... 63
Curve of uniformity coefficient.... 15
Cushion layer for pavements....65-66

Page
Cymblin Creek, Roubidoux sandstone on 99
Dade County, asphaltic sandstone in... 182
gravel supply in... 241
Daisy, road gravel pit, at...70, 211
St. Peter sandstone near... 131
Dallas County, Gunter sandstone in... 93
Dalton gravel pit... 202
Dams, concrete construction of... 62
Danby, St. Peter sandstone at... 143
Danville, St. Peter sandstone near... 115
Davis formation, referred to...89, 91
Dealers in sand, classes of...46-47
DeArmand, S. J., gravel pit of..204-205, 206
gravel pit of, illustrations...204, 205
Decaturville, granite at... 89
Decayed rock effect of, on specific gravity...18, 225
effect of, on concrete...11, 18, 61-62
in glacial gravels... 204
Decolorizing agents, in glass making..82, 83
Decorah formation, referred to...88, 171
Deer Creek formation, in table of formations... 87
Definition of sand... 1
Deltas, fine sands of large deltas... 4
Dent County, granite in... 89
Deposits of glass sand, size and extent.. 83
Depth of water suitable for pumping operations... 36
Derby formation, referred to...89, 91
DesMoines group, formations, in table of formations... 88
De Soto quadrangle, as a base map for work...XIV
Devonian, Beauvais sandstone...174-175
Clear Creek (?) chert, described...173-174
formation, in table of formations... 88
limestones, referred to... 109
residuum for road surfacing...70, 211
sandstone, discussed...170, 175-176
see also Phelps sandstone.
Dexter Creek, gravel from...242, 243
Dexter, sand handled by hand at... 31
Tertiary gravel near...71, 206, 242, 243
Diameter of wire used, in screens... 12
Differential weathering... 2-3
Dip, of asphaltic sandstone... 183
of Everton sandstone... 103
of St. Peter sandstone..115-116, 120, 145
Dipping sand, Nodaway River...240-241
Dirt, amount eliminated by dredge pumps... 10
content, of glacial gravels...203-208
of minor stream gravels...238-243
of Mississippi River sands...212-218
of Missouri River sands...219-224
of Ozark gravels... 225
of Tertiary sands and gravels...189-203, 206
see also mechanical analyses, washing, etc.
tests, by whom made... XV
how made on sands... 9-11
Dirty sands, difficulty in making gravity determinations on...20-21
Discordance, deceptive, between St. Peter and Joachim... 109
Page
Disseminated Lead District, Tertiary gravel in... 190
Distribution, geographic, in classifying sands... 7
stratigraphic, in classifying sands... 7
see also name of formation desired.
District of Columbia, filter sand specifications of...78-79
Doerun formation, referred to...89, 91
Dogtown, Ill., St. Peter sandstone, near...115, 116-117, 168
Dolomite, in sands, referred to...29, 133
see also Jefferson City, Joachim, etc.
Donnivant, Chas., Missouri River sand plant of... 221
Doolin Hollow, St. Peter sandstone along...119, 150
Douglas County, Roubidoux sandstone described in...98, 126
Douglas formation, in table of formations 88
Drag line, see cable drag line.
Drake, gravel plant at...38, 40, 43, 47, 215, 227-228, 242
Dredge, belt bucket type...233-234
illustrations of...32, 36
cable drag-line type...34-35, 229, 235-236, 238-239
illustrations of...34, 35
centrifugal pump type...10, 13-14, 35-36, 212-218, 219-224, 226-233, 235-236, 239-240, 242
illustrations of..36, 37, 213, 220, 222, 223
pumps, dirt and fine sand washed out by...10, 13-14
Dredging, methods of, described...34-36
season, length of... 39
Drift, referred to...283, 239, 241
see also till, glacial gravel, etc.
Drill holes, see well records.
Drilling, methods of...39, 146, 148, 154, 156, 158, 160, 163
Drum and cable, sand moved by...33, 39
see also Quarries.
Drum limestone in table of formations.. 88
Drying sand, method described...34, 44, 147, 154, 156, 159, 63, 235
plant for, illustration of... 44
Dryness, in engine sand...77-78
Dunklin County, sand handled by hand. 31
Tertiary gravel in...71, 192, 201-202, 206
Dunlap, John, sand shipped by... 237
Durability in moulding sands...75-76
Dust, in filter sands and gravels...79, 80
in gravel for railroad ballast... 72
see also clay, silt, dirt, etc.
Dutchtown, St. Peter sandstone near...102, 106, 131, 133
St. Peter sandstone, illustration of... 133
East St. Louis, market for sand and gravel...50, 227
Effective size, applied to concrete aggregate... 58
applied filter sands...78-80
by whom determined... XV
discussion of... 15
gravels of minor streams...238-243
Mississippi River sands...212-218

Page
Effective size applied—
Missouri River sands....219-224
Ozark gravels....225-238
St. Peter sand, table of....126, 127
see also mechanical analyses.
Eldridge, G. H., cited on asphaltic sandstone....184, 186, 187
Electricity, sand haulage by....39, 146
Elk Creek, Roubidoux sandstone on....99
Elk River, gravel from....241-242
Ellis, Joe, gravel pit of....193-199, 206
illustration of gravel pit of....194
Eminence formation, referred to....89, 91
Endless belt conveyor....38, 215, 217, 226, 227, 231, 233
illustrations of....40, 215
Engineering and Contracting, cited on cost of washing ballast....73
Engineering News, cited on ballast specifications....72-73
Engine sand, described....77-78
drying method described....43-44
Little Piney Creek sand used for....235
Missouri River sand used for....222, 223
plant, illustration of....44
production by years....45
Roubidoux sandstone used for....99
Enlargement of quartz grains....17
also see quartz enlargement.
Enterprise Sand and Mining Company, description of....143, 147-148, 149
moulding sand from....210
plant, illustrations of....34, 147
referred to....34, 39, 129, 130, 141
Eolian, limestone, referred to....5
sand defined....5
Error, per cent of, in specific gravity determinations....19-21
in void determinations....24, 25
Escarpment, Joachim-St. Peter....104, 118-120, 138, 141, 144, 145, 149, 153, 155, 158, 159, 161, 162, 164, 165
illustrations of....109, 145
Establishment Creek, escarpment along. 119
St. Peter sandstone along....138, 140, 166
Evanston, Ill., market for filter sand....214
Everton sandstone, areal extent of....101-103
chemical analysis of....122, 140
favorable localities for....105
illustration of....44
Jefferson County....142, 143, 149, 150
lithologic character of....104-105
map of, see St. Peter sandstone map.
mechanical analysis of....126
physiography of....104
referred to....88, 93, 109, 110, 111, 112, 113, 114, 117, 118, 119, 132, 134, 135, 157
Ste. Genevieve County....138-141
stratigraphic relations of....103
structure of....103-104
suitability for glass sand....105
thickness of....103
uses of....105
Expansion and contraction, as an agent forming sand....2
Facing sand, defined....77
Fanning Roubidoux sandstone near....100
Farmington anticline, Lamotte sandstone exposed on....90
Faulting, in Lincoln County....107, 115, 116-117, 130
in Perry County....106, 107, 116, 117, 130, 134, 135, 137, 138, 142
illustration of....132
in Ste Genevieve County....102, 103, 116-117, 119, 138, 174
Fauna, Aftonian (?), of glacial gravels..207
Favorable localities for glass sand....132, 136, 139, 150, 156, 160, 163, 164, 166, 168
Feldspar, in glacial gravels....206
in Mississippi River sands....211
sands, effect on specific gravity....18
in sand for sand lime brick....64
in sand, referred to....29
Feldspathic sand, origin and definition of 3, 6
specific gravity of....19
Feldspathic sandstone, in the Lamotte..90
see also Arkose.
Femme Osage Creek, St. Peter sandstone along....116, 161
Fence posts, concrete construction of...63
Feret's table of sand sizes....59
Fern Glen formation to....88, 177
Fernvale formation, referred to....88, 171
Ferromagnesian minerals, in Mississippi River sand....211
in sand, effect of on specific gravity..19
in sands, referred to....29
Ferromagnesian sand defined....6
Ferruginous gravel, see Lafayette (?) gravel.
Ferruginous layers, rejection of....45
Ferruginous St. Peter sandstone....128-130, 131, 132, 134, 135, 142 144, 147, 155, 167, 158
Ferruginous sand, analyses of....122, 125, 126, 144
defined....5
see also description of sands desired.
"Ferruginous sandstone" referred to....178-179, 180
Ferruginous strain, in the Everton sandstone....104
Fertilizer, green sand used for....6
Festus, St. Peter sandstone near,....XIV, 129, 143, 147, 148
Field, H. E., cited on composition of moulding sands....76
Field work....XIV
Filler in paper, sand for....86
Filter gravel, Meramec River....229
Filter sand, chemical composition essential for....30
described....78-80
plant....214
illustration of....43
referred to in classification....8
uniformity coefficient a test for....15
Fineness, see coarseness, and size of grain.
Fine sand, defined....7

Page
Fines, fluxing substances in 74
Fire clay, in Pennsylvanianian sandstone 180
Fire sand, chemical composition essential for 30
production by years 45
properties of 85
First Magnesian Limestone, same as Joachim.
First Sandstone, same as St. Peter.
Flagstone quarried from the Gunter sandstone 92
Flat Creek, sandstone on 171
Flat particles in filter sands and gravels. 80
Flint, see chert.
Floreffe, Pa., glass plant at 144
Flux, in fire and furnace sand 85
in moulding sands 74
St. Peter used for 50, 148
see also moulding sand and fire and furnace sand.
Foley, Cap au Gris fault near 117
St. Peter sandstone near 167, 168
Fold, at Crystal City 141
Folding in the St. Peter area 115-116
see also anticline, monocline.
Ford City, Pa., glass plant at 144
Form of grain, in sand, general discussion of 16-18
see also shape of grain, sharpness, roundness.
Formulae, for dirt content 9
for specific gravity 20, 21
for voids 23, 25, 26
for weight 27, 28
Fort Scott limestone in table of formations 88
Foundations, for sheet asphalt pavements 65
concrete construction of 62
Foundry bed sand from Steelville 237
Foundry sand, description of 73-77
see also moulding sand.
Fourche a du Clos Creek, St. Peter sandstone near 140
Fox Creek, glacial gravel along 207
Franklin County, escarpment in 119
glass sand plants in, illustrations 158, 159, 160
granite in 89
gravel plant in 229-230
Lafayette (?) gravel in 71
illustrations of 32, 174
mechanical analyses of sand and gravel from 242
St. Peter sandstone, analysis of 122, 123-124
description of 156-160
map of 152
mapping of XIV
referred to 49, 107, 112, 153, 155, 161
sand plant in 155
illustrations of 223, 229
Tertiary gravel in 190-191
Freeman, J. H., sand plant of 235
illustration of 44

Page
Freezing, as an agent in forming sand .. 2
effect of on sand shipping 39
French sand, defined 77
French Village, Lamotte sandstone at .. 90
Friability, of St. Peter sand .. 30, 40, 130, 142, 147, 149, 153, 157, 158, 159, 161, 164, 166, 167, 168
of sand for glass 81
see also hardness, cementation.
Frisco, see St. Louis and San Francisco Railroad.
Frost, as an agent in forming sand 2
Frosted grains, in the Everton sandstone 104-105
Fuel for glass sand development 83, 84
Fulton quadrangle, as a base map for work XIV
Furnace, for drying sand, described ... 43-44
illustration of 44
Furnace sand, properties of 30, 85
referred to in classification 8
St. Peter sandstone used for 50, 160
Fusion, effect on porosity of moulding sands 74
refractory sands remain unfused 30
Galesburg shale in table of formations .. 88
Garnet in sand, effect on color 8
Gasconade, in table of formations 89
Gunter sandstone member 92-93
Gasconade Fork, Roubidoux sandstone on 97, 99, 100
Gasconade River, sand plants on .. 35, 235-236
Gates Gyratory crusher 163
Gelsthorp, F., analyses furnished by 41-42, 123-124
cited on properties of glass sand ... 83
on value of washing sand 42
Geology of sand formation 87-244
Geographic distribution in classifying sands 7
Gerler, Clear Creek (?) chert near .. 173-174
Giboney, St. Peter sandstone near ... 135
Glacial formations in table of formations 87
Glacial gravel, decay in 61
description of 203-208
for ballast 73
for road surfacing 69, 71
illustrations of 204, 205, 207
in streams 239-241
Glacial sand, defined 5
excessive clay in 10, 52, 55, 56
Glacial wear, as an agent in forming sand 2
Glaciated area older than Pennsylvanian, gravel in 211, 238-239
Glaciated Pennsylvanian area, gravel in. 211, 239-241
Glacio-fluvial gravels, description of .. 203-208
illustrations of 204, 205, 207
Gladstone, Gunter sandstone near 92
Glasgow, Missouri River sand from 37, 47, 219, 221, 224
Glasgow Sand Company, Missouri River sand plant 221
Glaser, J. W., quarry of 157, 160
quarry of, illustrations 160

Page
Glass factory, illustrations of.....133, 145
Glass sand, analyses of.....121-126
Aux Vases sandstone unsuited for.... 179
Beauvais sandstone suitability for.... 175
belt, extent of..... 49
Bolin Creek sandstone unsuitability for..... 96
chemical composition essential for..29-30
color of..... 8
deposits of proper thickness, location, fuel supply..... 83
drying of..... 44
Everton sandstone, suitability for.... 105
favorable localities for,..... ....132, 136, 139, 150, 156, 160, 163, 164, 166, 168
Gunter sandstone, unsuitability for.92-93
Lamotte sandstone for.....90-91
markets for.....49-50
production of by years..... 45
production of, limits of..... 49
properties of.....80-84
quarries and plants, illustrations, Franklin County.....158, 159, 160
Jefferson County..... .....34, 42, 109, 145, 147, 148
St. Charles County.....155, 158, 160
St. Louis County.109, 145, 154, 155, 156
Roubidoux sandstone for.....93-100
St. Peter sandstone for....49-50, 105-170
Tertiary sandstone for..... 191
washing of.....41-42
Glasstetler gravel pit.....200, 206
illustration of..... 184
Glauconite sand defined..... 6
Glaze on pottery, sand for..... 86
Gneiss in Mississippi River sands..... 211
Gold-bearing sands defined..... 6
Gothite, possibly present in sands..... 29
Gordonville, St. Peter sandstone near.. 131
Graded aggregates for road surfacing..69-70
Graded gravel for railroad ballast..... 72
Graded sands, for bricklaying..... 53
for plastering..... 52
for asphalt pavements..... 66
reduction in voids, owing to..21-23, 58-60
Grading of sands, see also graded sands, voids, and size of grain.
Graduated tube, use in determining specific gravity.....19-20
in determining voids.....22-23
Grain elevators, concrete construction of..... 63
Grains of sand, cleanness of.....9-11
form of.....16-18
see also shape of grains and sharpness.
size of.....11-16
see also size of grain coarseness.
soundness of..... 18
Grand Tower formation, referred to...88,174
Granite City, as a market for Missouri sand..... 70
Granite, crushed for filter sands and gravels..... 79
decayed pebbles of in glacial drift.... 61
description of residual from.....89, 211

Page
Granite—
for road surfacing.....69, 71
in Black River gravels.....225, 231
in glacial gravels.....203, 204, 205
in Mississippi River sands..... 221
in table of formations..... 89
weathering of, chemically and mechanically..... 2, 3
Granularmetric analysis, see mechanical analyses.
Grassy Creek formation, referred to..88, 176
Gravel bar, illustration of..... 236
Gravel, definition of..... 1
dredging, illustrations of..... .....32, 34, 35, 36, 37, 41, 223, 229
see also Ozark streams.....225-238
for concrete, general discussion of...54-62
for railroad ballast, general discussion of.....72-73
for roads, general discussion of.....69-71
for roofing, general discussion of..... 63
for pavement foundations, general discussion of..... 65
from minor streams.....238-244
from Mississippi River..... 216
from Ozark streams.....225-238
from Salt River.....238-239
glacial.....203-208
illustrations of.....204, 205. 207
Lafayette (?), Franklin County, illustrations of.....32, 174
Scott County, illustrations of..... 194
see also Lafayette (?)
Producers, list of.....243-244
production by years.....45
pits, Benton.....199-200
Commerce.....193-199
Dunklin County.....201-202
Guilford..... 206
Maryville.....204-205
Pacific.....190-191
Stoddard County.....200-201
Versailles..... 190
screening, illustrations of.....40, 43, 229
sizes in commercial use..... 7
size that can be handled by pumps... 36
Tertiary.....71, 189-203, 206
washing of for concrete work..... 54
see also sand.
Gravity, sand haulage by..... 39
screening by means of, described.... 43
see also specific gravity.
Grays Summit, St. Peter sand from.... .....123-124, 157
Grays Summit White Sand Company's description of..... 123-124, 157-159, 160
illustrations of.....158, 159
Green color, in sands, what due to....8, 144
of Everton sandstone..... 104
of St. Peter sandstone..... .....45, 117, 122, 125, 126, 128
Greene County, gravel supply in..... 241
Northview sandstone in..... 177
Phelps sandstone..... 177
Vermicular sandstone in..... 176

Page
Greene, F. C., cited on glacial gravels..203, 207
on Pennsylvanian sandstone.....181, 186
Green sands, defined..... 6
Grinding sand, production by years.... 45
production of.....147, 154
properties of..... 84
Grout houses.....62-63
Grundy County ,glacial gravel in..... 207
Guilford, glacial gravel near..... 206
glacial gravels, illustration of.....205, 206
referred to..... 239
sand handled by hand at..... 32
Gumbo as railroad ballast, referred to.. 72
Gunter sandstone, described.....89, 92-93
Gutters, concrete construction of..... 63
Gyratory crusher, used to crush sand..40, 156, 163
Hahatonka, Gunter sandstone near.... 93
Hamburg, Tertiary gravel near..... 200
Hammer-mill, used to crush sand.....40, 142, 148, 154
Hand, loading sand by.....31, 32-33
unloading sand by..... 38
Hannibal, gravel plant near.....212, 227, 238-239
gravel plant, illustration of.....34, 35
market for Missouri River sand..... 221
sand plant at.....37, 40, 43, 73, 213, 215, 216, 217, 242
illustration of..... 216
Hannibal shale, referred to.....88, 176, 177
Hardness, for engine sand.....77-78
for filter sands and gravels.....79-80
for grinding sand..... 84
for road gravel..... 69
for sand-blast sand..... 85
for stone sawer's sand.....84-85
of Everton sandstone..... 105
of St. Peter sand.....39, 50, 130
see also friability, cementation, etc., also names of formations, as Roubidoux, etc.
Hardpan gravel, for filters..... 79
for road surfacing.....70, 71
occurrence of..... 211
Harrison Brothers, gravel plant of...36, 233
gravel plant, illustration of..... 36
Heating, as an agent in forming sand... 2
Heitman, Henry, gravel pit of.....205-206
Hematite, effect on specific gravity of sands..... 19
little altered by weathering..... 3
present in sands..... 29
Henley, gravel plant at..... 234
Henrietta formation, referred to.....88, 182
Henry County, gravel supply in..... 241
Pennsylvanian sandstone in..... 181
Tertiary gravel in..... 189
Herculaneum, escarpment near..... 119
moulding sand from..... 210
analysis of..... 210
St. Peter sandstone used for flux at... 50
St. Peter sandstone near..34, 129, 143, 147
sand plant at, illustrations of.....34, 147
Hermann market for Missouri River sand..... 220
Page
Hermann quadrangle, as a base map for work.....XIV
Hertha limestone in table of formation.. 88
Higginsville, asphaltic sandstone near..183, 184, 186-188
Highland, St. Peter sandstone near.... 134
Hilderbrand, St. Peter sandstone near..110, 134
Hinds and Greene, cited on asphaltic sandstone..... 186
Hogan, L. S., well of..... 135
Hogoboom, W. E., cited on the Roubidoux sandstone..... 99
Holt County, stream gravels from.....240-241, 242
Holt Summit, St. Peter sandstone near.. 170
Hook, Jas., gravel pit of..... 205
Houses, concrete construction of..... 62
Howard formation, in table of formations 87
Hudson River formation, in table of formations ,,,

Page

Iron County, Lamotte sandstone in.... 90
Iron Mountain Railroad, see St. Louis, Iron Mountain and Southern Railroad.
Iron oxide, as flux in moulding sands....30, 74, 75, 76
content, for fire and furnace sand.... 85
for glass sand..... 80, 82, 83, 144
of St. Peter sandstone.....121-126, 128-130
determined in analyses of sand..... 29
effect on color of sand..... 5
effect on specific gravity of sand..... 19
little altered by weathering..... 3
removed by washing.....9-11, 41-42
stained layers rejected..... 54
uses of sand for which a knowledge of is essential..... 30
see also ferruginous sand, hematite, limonite, and chemical analyses.
Iron, test for in glass sand..... 81
Isle du Bois Creek, escarpment along.. 119
Everton sandstone on.....102, 107
St. Peter sandstone along...138, 141, 142
Jackson County, asphaltic sandstone in.....182, 183
Missouri River sand from...222-223, 224
sand plants in, illustrations of.....42, 222
Jackson Lime and Quarry Company, analysis of St. Peter sandstone by.122, 133
Jackson, St. Peter sandstone near.....106, 113, 123-124, 131, 132, 133
Jasper County, gravel supply in..... 241
Tertiary gravel in..... 189
Jaw crusher.....157, 158
Jefferson City, market for Osage River gravel..... 234
market for Valda gravel..... 236
Missouri River sand from.....219, 220
sand plant in.....37, 47
illustrations of..... 220
sidewalk specifications referred to... 63
Jefferson City formation, described briefly.....100-101
mechanical analysis of..... 126
relation to St. Peter and Everton..109-111
referred to....89, 110, 111, 112, 116, 118, 119, 120, 128, 129, 161, 162, 163, 164, 166
Jefferson City, St. Peter contact.....109-111
Jefferson City Sand and Gravel Company's plant..... 220
illustrations of..... 220
Jefferson County, Devonian sandstone in..... 175
Everton sandstone in...102, 103, 104, 105
glass factory in, illustration of..... 133
gravel plant in..... 233
illustration of..... 36
Jefferson City—St. Peter contact in.. 110
mechanical analysis of Jefferson City sandstone..... 126
of St. Peter sandstone..... 126
of sand and gravel from..... 242
Mississippi River sand from.....213-215
Pittsburgh Plate Glass Company's quarry, map..... 148
Roubidoux described..... 100

Page

St. Peter escarpment, illustration of.... 109
St. Peter sandstone, analyses of.....122, 123-124, 125, 126
description of.....141-152
illustrations of.....34, 42, 145, 147
map of.....141, 152
mapping of.....XIV
referred to..34, 49, 107, 112, 115, 138, 164
sand plant in, illustration of.....43, 145, 147, 213
Jester, see Cole and Jester.
Joachim Creek, centrifugal pumps used on..... 35
escarpment along..... 119
gravel from.....225, 233, 242
gravel plant on, illustration..... 36
St. Peter sandstone along.....148, 149
sand shipping points on..... 47
Joachim formation, description of..... 171
mechanical analyses of..... 126
referred to.....88, 112, 113, 129, 130, 140, 148, 149, 150, 152, 153, 155, 159, 161, 162, 167, 168, 169
Joachim—St. Peter contact.....135-171
illustrations of..109, 145, 147, 154, 155, 60
Joachim-St. Peter escarpment..104, 118, 120, 138, 141, 144, 145, 149, 153, 155, 158, 159, 161, 162, 164, 165
illustrations of.....109, 145
Johnson County, Pennsylvanian sandstone in..... 181
Jonca Creek, Lamotte sandstone on.... 91
Kansas, market for Missouri sand.....46-47, 50, 159
Kansas City, distribution of sand from.46-47
market for Osage River gravel..... 234
for St. Peter sand..... 50
for Valda gravel..... 236
method of handling clam shell in..... 37
Missouri River sand from.....219, 222-223, 224
sand plants in, illustrations of....40, 222
sidewalk specifications referred to.... 63
Kansas City formation, referred to...87, 182
Kansas City, Ozark, and Southern Railroad, Roubidoux deposits on..... 99
Kansas City Southern Railway, ballast supply..... 242
Kansas (Kaw) River sand described.223, 224
referred to..... 222
Kaolin in sands, effect on specific gravity 19
little altered by weathering..... 3
referred to..... 133
usually carries the alumina of sands.. 29
see also alumina.
Kaw River sand, as a trade name..... 7
competition with..... 48
described.....222, 223, 224
Kenderdell, Pa., glass sand quarry at... 144
Kentucky, Louisville, market for filter sand..... 214
Kentucky, natural asphalt sands.....67, 68
Keokuk formation, referred to.....88, 178
residuum from for road surfacing.... 70
Keokuk sand, competition with..... 48
Killian, R. D., assistance rendered by..XVI
Kimmswick formation, referred to...88, 171

Page
Kinderhook sandstone, referred to...88, 176
Kirksville, market for Canton sand.... 217
Klondike, escarpment near..... 119
ferruginous sand at..... 129
glass sand plant at.....34, 39, 155
illustrations of.....155, 158, 160
St. Peter sandstone, analysis of.....
.....122, 123-124
mechanical analysis of..... 126
near.....XIV, 49, 112, 130, 157, 159, 161-163, 164
Knob View, Roubidoux sandstone near.. 100
Knox County, gravel supply in.....238, 239
Kokomo, Ind., glass plant at..... 144
Labette shale, in table of formations.... 88
Laboratory studies, by whom made.... XV
Laclede County, Roubidoux described.. 99
Ladore shale in table of formations..... 88
Lafayette County, asphaltic sandstone in.....181, 182, 183, 185
gravel supply in..... 241
Missouri River sand from...221-222, 224
Pennsylvanian sandstone in..... 181
Phelps sandstone in..... 177
Lafayette formation in table of formations..... 87
Lafayette (?) gravel, as a trade name... 7
description of..... 71
Franklin County.....190-191
illustrations of.....32, 174
Morgan County..... 190
Scott County.....194, 200
illustrations of..... 194
Stoddard County..... 201
Lake sand, defined..... 5
Lamotte sandstone..... 89
chemical analysis of..... 90
description of.....89-90
conglomerate in.....89-91
for glass sand.....90,91
mechanical analysis of.....89, 126
referred to.....4, 92
Lane shale, in table of formations..... 88
Lansing formation, in table of formations 88
LaSalle County, Illinois, analysis of St. Peter sandstone from..... 125
Lawrence County, gravel supply in.... 241
Lawrence shale, referred to.....88, 181
Lead District, Tertiary gravel in..... 190
LaChatalier bottle, used in determining specific gravity..... 20
Lecompton, shale, in table of formations 87
Lee, L. T., gravel pit of..... 204
Lee, Wallace, cited on the Roubidoux sandstone..... 93
Leeper, S. L., gravel bar of..... 232
Length of dredging season..... 39
Letter of transmittal.....XIII
Lewis County, gravel supply in..... 238
Mississippi River sand from..... 217-218
sand plant in, illustrations.....37, 216
Lexington, Missouri River sand from..
.....219, 221-222, 224
sand handled by hand at..... 31
Lexington Triumph Press Brick Company, Missouri River sand plant of..
.....221-222

Page
Liberal, asphaltic sandstone near..... 183
Lick Fork Creek, Roubidoux sandstone on..... 99
Lignite, as an impurity in sand.....10-11
effect, on sand.....11, 52, 53, 54, 56
on specific gravity..... 18
in Mississippi River sand.....212-213
in Missouri River sands..52, 218-219, 222
Lignitic sands, method of washing described..... 41
Lime, as a flux.....30, 74, 75, 76, 85
determined in analyses of sand..... 29
content in filter sands and gravel....79-80
in fire and furnace sand..... 85
in moulding sands.....74, 75, 76
of St. Peter sands.....23-126
form in which present in sand..... 29
uses of sand for which a knowledge of is essential..... 30
Limestone, bituminous..... 182
in filter sands and gravels..... 79
in glacial gravels.....204, 205, 206, 207
in gravels for road surfacing..... 71
weathering of..... 2, 3
Limonite, a common impurity in sands.. 29
as a flux..... 30
in sands, effect on specific gravity.... 19
little altered by weathering..... 3
referred to..... 133
Lincoln County, faulting in.....116-117
gravel supply in..... 238
St. Peter sandstone, analysis of.....
.....122, 123-124
descriptions of.....107, 126, 167-170
map of..... 168
referred to.....49, 138
thickness in..... 115
Vermicular sandstone in..... 176
Lindley, glacial gravel near..... 207
List of illustrations.....X-XII
List of sand and gravel producers....243-244
Lithium, St. Peter sandstone near...137, 138
St. Peter sandstone, near, lilustration. 132
Lithologic character, of St. Peter sandstone.....121-130
see St. Peter sandstone, lithologic character.
Little Bear Creek, St. Peter sandstone along.....116, 164
Little Dry Fork, gravel from..... 238
Little gravois Creek, gravel plant on 236-237
Little Piney Creek, gravel bars on, illustrations of..... 236
gravels from.....225, 234-236, 242
Little Saline Creek, Beauvais sandstone on..... 175
Little Saline formation, referred to..88, 174
Little Tavern Creek, gravel from..... 234
Lixville, St. Peter sandstone near..... 134
Loading trap.....191, 232, 234
illustration of..... 32
Loading sand, see sand, clam shell, cable drag line.
Loam, in gravel for railroad ballast.... 72
in filter sands and gravels.....79, 80
in moulding sands..... 76
see also dust, clay, dirt, organic matter.

Page
Location of glass sand deposits 83
see also favorable localities.
Loess, along Missouri River 161
degree of compacting 39
heavy, in Cape Girardeau County . 120, 131
moulding sands from 210
overburden 148, 155, 158, 160, 162, 190, 201, 202, 208
illustrations of 156, 194
Longtown, glacial (?) pebbles near 203
Loss of sand, in screen tests 12-13
Louisiana, as a sand shipping point 47
belt conveyors in use at 38
Mississippi River sand from 213, 218
Louisiana formation, referred to 88, 176
Louisville, Kentucky, market for filter sand 214
Loutre River, St. Peter sandstone along 116, 165, 166, 167
Love Branch, gravel from 238, 242
Lower Helderberg formation in table of formations 88
Lowland, inner, referred to 120
McBride, Aux Vases sandstone near 126, 138, 178-179
faulting near 116
St. Peter sandstone near 107
McDonald County, gravel supply in . 241, 242
McKittrick, St. Peter sandstone near ... 116
Macon County, glacial gravel in 207
Madison County, Lamotte sandstone in . 90
Magnesia, as flux in moulding sands 30, 74, 75, 76
determined in analyses of sand 29
content, for filter sands and gravels. 79, 80
for fire and furnace sand 85
for glass sand 81, 82, 83
of St. Peter sands 123-126
form in which present in sand 29
uses of sand for which knowledge of is essential 30
see also chemical analyses.
Magnetite in sand, effect on color 8
effect on specific gravity 19
Magnetite sand, defined 6
Maitland, sand plants at 33, 38
stream gravels from 240-241, 242
Maltha, in natural asphalt sands 68, 185
Managers, Board of II
Manganese steel lining of pumps, cut out rapidly 35
Mansfield, Roubidoux sandstone near .. 99
Map, Pittsburgh Plate Glass Company's mine 148
St. Peter sandstone in Callaway and Montgomery Counties 168
in Cape Girardeau County 131
in Jefferson County 141
in Jefferson, Franklin, and St. Louis Counties 152
in Lincoln County 168
in Perry County 134
in Ste. Genevieve County 138
in Warren and St. Charles Counties. 161
State of Missouri, location of sand producers 243
Page
Marbut, C. F., cited on Gunter sandstone 92
on Roubidoux sandstone 97
on Tertiary 190, 191
Maries County, Roubidoux sandstone described 87
Maries Creek, gravel from 234, 242
Roubidoux sandstone on 97, 98
Marion County, gravel supply in 238
Mississippi River sand from 216-217
sand plant in, illustrations 216
Vermicular sandstone in 176
Markets for glass sand 84
for other sand 46-50
Marl, effect of on strength of concrete .. 11
Marshall, referred to 187
Maryville, glacial gravels near 204-206
gravel pit at, illustrations of 204, 205
market for Missouri River sand 224
referred to 239
sand handled by hand at 32
Massachusetts, filter sand specifications of 79
Mast, for handling sand, illustrations .. 34, 35, 41, 220, 223, 229
for operating clam shell, described ... 37
Materials Laboratory of United States Geological Survey, tests by 223, 228, 230-231
Matrix in glacial gravels 204
Mattox and Younger, gravel business of. 241
Mechanical analyses, asphaltic sand stone 185, 187
Aux Vases sandstone 126, 179
Black River gravel and sand .. 231-233, 242
Commerce sandstone 126, 192
curves 15
Dexter Creek sand and gravel 242, 243
Elk River gravel 242, 243
glacial gravel, Guilford 206
Maryville 205-206
Putnam County 206, 207
table 206
Joachim Creek, gravel and sand ... 233, 242
Kaw River sand 224
Lamotte sansdtone 90, 126
Little Gravois Creek gravel 237, 242
Little Piney Creek sand 235, 242
Maries Creek, gravel and sand 234, 242
Meramec River sand and gravel, Drake 227-228, 242
Morsches Spur 230-231
Moselle 230, 231
Pacific 229, 230, 242
table of 242
method of recomputing screen rests .. 13
minor stream gravels, table of 242
Mississippi River sand, Canton 217-218, 224
Cape Girardeau 213, 224
Crystal City 214, 224
Hannibal 216-217, 224
Louisiana 218, 224
St. Louis 215, 216, 224
summary of 12, 224

Mechanical analyses— Page
Missouri River sand, Glasgow...221, 224
Kansas City.....222-223, 224
Lexington.....221-222, 224
St. Charles.....220, 224
St. Joseph..... 224
table of..... 224
moulding sands, Herculaneum..... 210
St. Louis..... 209
Nodaway River sand and gravel.....240-241, 242
Platte River sand..... 224
Roubidoux sandstone.....95-96
St. Peter and other sandstones, tables. 126
St. Peter sandstone..... 15
Salt River gravel.....238-239, 242
Spring Fork gravel.....236, 242
table of glacial sand and gravel..... 206
Mermec and minor streams, gravel of..... 242
Mississippi and Missouri River sands..... 242
St. Peter sandstone..... 126
Sandstone other than St. Peter..... 126
Tertiary sand and gravel..... 206
Tertiary fine sand, commerce....199, 206
Tertiary gravel and sand, Benton.....199-200, 206
Commerce.....193-199, 206
Stoddard County.....200-201, 206
summary..... 206
Whittenberg Creek sand.....237, 242
Mechanical weathering, in the formation of sand..... 2
Medium sand, defined..... 7
Mehl, M. G., cited on chert in base of St. Peter..... 111
mapping by..... XV
Melting sand, production of.....147, 154
Memphis, Tenn., sand plant at.....215, 227
Menefee, G. T., gravel plant of..... 236
Menfro, St. Peter sandstone near, illustration..... 132
Meramec Portland Cement and Materials Company's plant, description of.....215, 228-229
illustrations of.....37, 43, 213, 215
Meramec River, escarpment along..... 119
filter sand from..... 78
gravel plants on.....35, 38, 59, 213, 215, 225, 226-231
illustrations of.....37, 40, 43, 223, 229
gravels from, as a trade name..... 7
uses of.....227-229
mechanical analyses of sand and gravel from..... 242
Pennsylvanian sandstone near..... 180
roofing gravel from..... 63
St. Peter sandstone along.....141, 142, 152, 153, 155, 156, 157, 158, 159, 165
sand analysis referred to..... 29
sand shipping points on.....47, 237
screened ballast from..... 73
screening plants, referred to.....43, 58
Tertiary gravel along..... 190
Meramec Springs, referred to..... 226
Roubidoux sandstone near..... 95

Page
Mesh of screens used for testing sand..11-13
Mesh tests, same as mechanical analyses.
Metamorphic rocks, weathering of chemically..... 3
Metz, G. F., screen tests by..... XV
Mexico, market for sand.....218, 221
Mica, harmful in concrete aggregate..... 62
Micaceous nature of asphaltic sandstone. 184
Micaceous sand defined..... 6
Mill Creek, Roubidoux sandstone on..... 99
St. Peter sandstone along...167, 168, 169
Miller County, gravel plant in.....236-237
Gunter sandstone in..... 92
Pennsylvanian sandstone in..... 180
Roubidoux sandstone referred to.93, 94, 96
Millerville, St. Peter sandstone near.113, 131
Millheim, St. Peter sandstone near..... 134
Mill Spring, Black River gravel and sand at.....232-233, 242
gravel at, illustration of..... 236
gravel plant at.....32, 33, 34
Mine Lamotte, Lamotte sandstone at.. 90
Mineola, St. Peter sandstone near.....XIV, 106, 116, 166
Mineral content, effect on naming of sands..... 6
see also classification of sand.
Mining sand, see tunnel methods.
Minor uses for sand..... 86
Mississippian, areas of stream sands and gravels of..... 211
Mississippian formations, fossils of in Tertiary gravel..... 193
gravel supply from.....238, 241-242
referred to.....88, 117, 239
residuum from..... 211
Mississippi River and Bonne Terre Railroad, glass sand along.....145, 148, 150
sand and gravel plants on..... 214
Mississippi River, escarpment along.119-120
faulting along..... 116
St. Peter sandstone near..XVI, 106-107, 114, 115, 116, 131, 133, 137, 138, 141, 135, 168
Mississippi River sand, analysis referred to.....29, 212
as a trade name..... 7
description of.....211-218
dirt in pumped samples..... 10
for engine sand..... 78
for filters..... 78
for pavement cushion layers..... 66
lignite in..... 52
low uniformity coefficient of..... 58
mechanical analysis tables..... 224
mottled color of..... 8
plants for production, illustrations of..37, 38, 39, 43, 213
referred to..... 172
shipping points for..... 47
uses of.....213-218
Missouri group, formations in, table of formations, in.....87-88
Missouri, Kansas and Texas Railway, glass sand on.....63, 165
Missouri Pacific Railway, asphaltic sandstone along..... 187

Missouri Pacific Railway— Page
glass sand along....155, 156, 159
gravel bar, illustration.... 236
gravel plants on....227, 228, 232, 233, 236
loading trap referred to.... 32
sand plants on....220, 222
Missouri River, escarpment along...119-120
glacial boundary near.... 203
glacial gravel near.... 207
lignite from, in Mississippi River sands.... 213
referred to....239, 241
St. Peter sandstone near.... XIV, 106, 107, 156, 157, 158, 161, 162, 166
Missouri River Sand and Gravel Company's plant....220, 221
illustrations.... 38
Missouri River sand, analysis referred to....29, 219
as a trade name.... 7
description of....211, 218-225
dirt in unwashed sample.... 10
excessive clay in.... 55
for asphalt pavements.... 66
for engine sand.... 78
for pavement cushion layer.... 66
lignite in....41, 52
low uniformity coefficient of.... 58
method of handling....31, 32, 35, 37, 43
mechanical analysis, table.... 224
motted color of.... 8
plants for production of, illustration of....38, 39, 40, 41, 220, 222, 223
shipping points for.... 47
uses of....218-224
Missouri Silica Company, analysis of St. Peter sand from....123-124
Moberly, market for Missouri River sand.... 221
Monazite sands defined.... 6
Moniteau County, Devonian sandstone in.... 175
Monoclines in the St. Peter area.... 116
see also folds.
Monolithic construction....62-63
Monroe County, gravel supply in.... 238
Montgomery County, Devonian sandstone in.... 175
escarpment in.... 118
Jefferson City—St. Peter contact in.. 110
Joachim-St. Peter contact in.... 109
mechanical analysis of Jefferson City sandstone.... 126
of Pennsylvanian sandstone.... 126
of St. Peter sandstone.... 126
St. Peter sandstone, description of.... 112, 165-167
St. Peter sandstone, map of.... 166
St. Peter sandstone, mapping of....XIV
St. Peter sandstone, referred to.... 49, 106, 107, 116, 164
Moore, R. C., cited on the Northview sandstone.... 177
Moreau Creek, Roubidoux sandstone on. 98
Moreau sandstone, same as Roubidoux.
Morgan County, analyses of sandstone from....123-124
Gunter sandstone in.... 92
Morgan County— Page
Pennsylvanian sandstone in.... 181
Roubidoux sandstone described.... 97
Tertiary gravel in.... 190
Morrison Ice and Fuel Company's plant, description of....38, 213
Morsches Spur, Meramec River gravel and sand from....230-321
Mortar, for brick laying, sand suited for.... 53
for plastering, sand suited for....51-53
for stone masonry, sand suited for.... 54
strength tests on, from Commerce sand.... 196
Moselle, Meramec River gravel and sand from....230-231
Motted color in sand, what due to.... 8
Moulding sand, chemical composition essential for.... 30
chemical analyses of....76, 209, 210
description of....73-77
from Herculaneum.... 210
from South St. Louis....208-209
from Steeleville.... 237
pits, illustrations of.... 208
production of, by years.... 45
referred to in classification of sand.... 8
St. Peter sandstone as.... 50, 148, 149, 155, 159, 160, 163
Mound City, market for Missouri River sand.... 224
Mount Vernon, Ohio, glass plant at.... 144
Mozingo, J. S., gravel pit of.... 205
Muddy Creek, escarpment along.... 119
Mud seams, analyses of...122, 125, 126, 144
in the St. Peter sandstone.... 117, 128, 145, 146, 152, 155
Mulienburg, G. A., cited on asphaltic sandstone....181, 186
Mules, sand haulage by.... 39
Murphy, W. J., Black River gravel and sand business of.... 232
Natural asphalt sands, properties of..66-69
Natural bridge, Cliffdale Hollow, Jefferson County.... 119
Navigable streams, permission to dredge from....47-48
Nebraska, Platte River sand referred to.... 34, 224
Nesting sieves, in sand tests.... 12
Newburg, mechanical analyses of sand and gravel from.... 242
sand bar near, illustrations.... 236
sand plant at.... 235
sand plant at, illustration of.... 44
New Madrid County, Tertiary gravel in.... 192
New Scotland formation, referred to.... 173
Newton County, gravel supply in.... 241
Tertiary gravel in.... 189
Niagara formation, in table of formations.... 88
Niangua River, Gunter sandstone on..92, 93
Roubidoux sandstone on.... 99
Nodaway County, decay of gravels in.. 61
excessive clay in sand and gravel of..55, 56
glacial gravels in....203-206, 207
gravel pits in, illustrations...204, 205, 207

Nodaway County— Page
mechanical analyses of gravel and sand from 206, 242
sand handled by hand in 32
steam gravels from 239-240
Nodaway River, sand and gravel from 239-241
uses of 239-241
low uniformity coefficient of sands from 58
mechanical analyses of sand and gravel from 242
sand dredging on 33, 35
Noel, gravel from 242
Noix limestone, referred to 88, 172
Norman, F. M., gravel business of 243
North Jefferson, St. Peter sandstone near 170
North Vernon as a market for Missouri sand 50
Northview sandstone, described 177
referred to 88, 176
Oak Ridge, St. Peter sandstone near 106, 131
O'Fallon quadrangle, as a base map for work XIV
Ohio, glass plant in 144
Oklahoma, as a market for Missouri sand 47, 50
natural asphalt sands from 68, 69, 185
One Hundred and Two River glacial gravels near 204-206
Ontario, filter sand specifications of 79
Oolite, siliceous, in the Roubidoux sandstone 94
Openings of sieves used in sand tests ... 12
Open pit quarries, see quarries.
Oran, Tertiary gravel near 200
Ordovician formations, in table of formations 88
Oread limestone, in table of formations .. 88
Orange peel dredge, referred to 37
Organic matter, in asphalt pavement sand 67
in concrete aggregate 11, 54, 56, 57
in filter sands and gravels 79, 80
in glass sand 82
in moulding sands 76
in pavement cushion layer sand 65-66
in St. Peter sandstone 133
in sand, discussed ... 9-11, 29-30, 52, 53, 54
Origin of sand, described 1-4, 5
Orthoclase in sands, effect on specific gravity 19
Orton, Edward, cited on Kentucky asphalt sands 68
Osage City, as a sand shipping point ... 47
see also Osage River.
Osage County, gravel in 234
loading trap in 32
mechanical analysis of sand and gravel from 242
Roubidoux described 97
Osage Fork, Roubidoux sandstone on ... 9
Osage River, gravel from 63, 225
gravel plant on 35, 38, 40, 43, 233-234
illustrations of 32, 36, 41
Gunter sandstone on 92, 93
Roubidoux sandstone on 96, 97, 98
sand shipping points on 47

Osage River— Page
Tertiary gravel along 189
tributaries as a source of gravel, referred to 32
Osage River Gravel Company's plant .. 233-234
illustrations of 32, 36, 41
Ottawa, Illinois, analysis of St. Peter sand from 125
analysis of slime from 42
method of sand quarrying at 146
St. Peter sandstone at 169
Ottawa Silica Company, analysis of St. Peter sandstone from 125
Otterville, market for Missouri River sand 220
Outcrop of St. Peter sandstone 106-108, 131, 134, 138, 141, 152, 156, 161, 163, 164, 165, 166, 167
Overburden, general nature of 39
in exposures 133, 136-138, 139-141, 150-152, 164, 166, 167, 169
in pits 174, 190, 198, 201, 202
illustrations of 194, 204, 205, 207
in quarries 145, 148, 149, 150-151, 153, 155, 156, 158, 159, 160, 162-163
illustrations of 42, 145, 147, 154, 155, 156, 160
till 203, 204, 205
see also Joachim and loess.
Ozark County, Roubidoux sandstone in, described 98
Ozark dome, nature of 115-116, 118, 145
Ozark gravels, as ballast 73
little decay in 61
referred to 238, 239, 241, 243
smoothness of surfaces 61
Ozark region, abundant gravel of ..... 62-63, 225-238 ...
Everton sandstone in 103
local sand markets in 46
Pennsylvanian sandstone in 180-181
Roubidoux sandstone in 89-90
St. Peter sandstone in 106
Tertiary described 189-191
Ozark sand, for blast work 85
for engine sand 78
for fire and furnace sand 85
Ozark sands and gravels, low specific gravity of 18
Ozark stream sands and gravels 211, 225-238
Pacific Cement Gravel Company's plant, description 32, 190-191
illustrations 32, 174
Pacific Glass Sand Company, chemical analysis, of St. Peter, sandstone from 123-124
mechanical analysis, of St. Peter sandstone from 126
plant, description of .40, 109, 153-155, 156
illustrations of 145, 154, 155
Pacific Plate Glass Company, analysis of St. Peter sandstone by 123-124
Pacific, as a sand shipping point 47
escarpment near 119
ferruginous sand at 129
filter gravel from 78, 79

Pacific— Page
glass sand plants in, description of....32, 40, 43, 153-155
illustrations of....109, 145, 154, 155
gravel plants near....32, 33, 35, 190-191, 229-230
illustrations of....32, 174, 223, 229
Joachim-St. Peter contract at.... 108
Lafayette (?) gravel near....71, 190-191
loess overburden at.... 39
mechanical analyses of St. Peter sandstone from.... 126
of sand and gravel from.... 242
St. Peter sandstone, analyses of...123-124
near....XIV, 107, 109, 112, 143, 153, 155, 156, 157, 158, 159, 161, 164
stone sawers' sand secured at.... 45
Tertiary gravel at....71, 190-191
Pacific sandstone, same as St. Peter.
Paleozoic formations, in table of formation....87-89
Panama Canal Commission, cited on composition of moulding sands.... 76
Parr, S. W., cited on sand lime brick... 64
Parting sand, defined.... 77
Pavement, asphalt....66-69
cushion layer for....65-66
foundations for.... 65
Paving sand, asphalt sandstone....181-189
discussion of....64-69
Mississippi River sand suited for.... 66
Missouri River sand suited for.... 66
production by years.... 45
referred to in classification.... 8
Pawnee limestone in table of formations 88
Peat, see also lignite.
Peneplain, Ozark, referred to.... 120
Pennsylvania, glass plants in....83, 143, 144
Pennsylvanian areas, stream sands and gravels of.... 211
Pennsylvanian formations, asphaltic sandstone from....181-189
description of....180-189
gravel derived from....239-241
in North Missouri.... 181
in Ozark region....180-181
referred to....87-88, 108, 126, 175
Permeability in moulding sands.... 75
Permission to dredge, where to secure..47-48
Perry County, Aux Vases sandstone in....178-179
Aux Vases sandstone, chemical analysis of.... 179
mechanical analysis of.... 126
Clear Creek (?) chert, described....173-174
referred to....34, 70, 73, 211
escarpment in....118, 120
Everton sandstone in....102, 103
relations of to St. Peter....111-112
faulting in....116, 130, 142
glacial (?) pebbles in.... 203
Jefferson City-St. Peter contract in....110, 111
Joachim formation in.... 171
Joachim-St. Peter contact in.... 108
Renault sandstone ,referred to.... 180
Roubidoux sandstone described.... 100

Clear Creek— Page
St. Peter sandstone, descriptions of....134-138
distribution of....106, 107
illustrations of.... 132
map of.... 134
mechanical analysis of.... 126
referred to, XIV....40, 112, 115, 117, 129, 131
thickness of.... 114
Thebes sandstone in.... 172
tripolitic chert in, illustration of.... 174
Wittenburg silica deposit, referred to....34, 70, 73, 211
Perry County Public Utilities Company, well of.... 135
Perryville, escarpment near....118, 119, 120
Everton sandstone near.... 117
St. Peter sandstone near....106, 112, 129, 134, 135, 136
Pettis County, gravel plant in.... 236
mechanical analysis of sand and gravel from.... 242
sandstone in....170, 171
Petrolene, in asphalt sands.... 185
Petroleum, in asphalt sands.... 185
Phelps County, cable drag line in.... 35
gravel from....234-236, 238
mechanical analyses of sand and gravel from....126, 242
Pennsylvanian sandstone in.... 181
Roubidoux sandstone described....93-96
sand bars in, illustrations of.... 236
sand plants in, illustrations of.... 44
Phelps sandstone, described.... 177
referred to....88, 175, 176
Phosphorus in green sands.... 6
Photographs, list of....X-XII
Physical tests of Portland cement used in tests of Commerce gravel.... 195
Physiography of the St. Peter belt..118-120
Picnometer bottle, used in determining specific gravity....20-21
Pike County, gravel supply in.... 238
Mississippi River, sand from.... 218
referred to.... 239
Vermicular sandstone in.... 176
Pillars, area of in sand mine.... 146
Pillman Brothers, sand plant of....235-236
Piney Creek, Roubidoux sandstone on.. 100
see also Little Piney Creek.
Pioneer Sand Company's plant, description of....223-224
illustrations of....39, 223
Pittsburg Plate Glass Company, analysis, chemical, of St. Peter sandstone from....41-42, 123-124, 125, 126
analysis, mechanical, of St. Peter sandstone from.... 126
plant, description of....143-147, 149
illustrations of....42, 133, 145
map of.... 148
referred to....40, 83, 128, 130, 141, 143
Placer gold, in sand and gravels.... 6
Plagioclase in sands, effect on specific gravity.... 19

Page
Plastering sand, Gunter sandstone for..92-93
properties of.....51-54
referred to in classification..... 8
Plat of uniformity coefficient..... 15
Platte County, Pennsylvanian sandstone in..... 181
Platte River sand, competition with... 48
described..... 224
for asphalt pavements..... 66
referred to..... 34
Plattin Creek, escarpment along..... 119
St. Peter sandstone along.....116, 145, 148, 149
Plattin formation, referred to...88, 130, 171
Plattsburg limestone, in table of formations..... 88
Pleasanton sandstone, referred to.....88, 181, 182, 183
Pleistocene sand and gravel, as a trade name..... 7
description of.....203-211
Polishing sand, production of by years.. 45
properties of..... 84
Polishing powders, sand for..... 86
Pontton pipe line, described..36, 217, 235,236
illustration of..... 37
Poplar Bluff, as a sand shipping point.. 47
Black River gravel and sand from.....231-232, 242
sand plant at.....32, 38
illustration of..... 229
Porosity, in moulding sands..... 75
see also voids.
Porphyry, in Mississippi River sands... 211
Portland Cement used in tests of Commerce gravel..... 195
Potash, in green sands..... 6
presence of in sands.....29-30
Potosi formation, referred to.....89-91
Potter, B. W., cited on Cap au Gres fault 117
on St. Peter sandstone.....115, 168
on Vermicular sandstone..... 176
Powell formation, described briefly..89, 101
Pre-Cambrian, description of residuum from..... 89
in Black River gravels..... 231
in table of formations..... 89
Preparation of sand for the market...40-45
Price, affected by competition.....47, 48-49
of glacial gravels.....204-206
of glass sand..... 80
of moulding sand..... 73
of paving sand..... 64
of roofing gravel..... 63
per ton of sand and gravel, by sources. 46
by uses..... 48
see also cost per ton.
Proctor Creek, Gunter sandstone in.... 92
Proctor formation, referred to.....89, 92
Producers of sand and gravel, list of..243-244
Production of sand 31-50
by sources..... 46
by uses and years..... 45
see also St. Peter sand, bank sand, etc., and names of producers or location.
Properties of sand.....8-30
for bricklaying..... 53
Properties— Page
for plastering.....51-53
for stone masonry..... 54
see also sand, properties of.
Prospecting for sand, methods.....44-45
Pueblo, Colorado, market for Osage River gravel..... 234
Pulaski County, Roubidoux sandstone, described..... 99
Pumped sand, cleanliness of..... 10
coarseness of.....13-14
washed by pumping..... 36
Pump, see centrifugal pump
Pundemann, Theo., sand business of..219-220
Purity, of sand for glass..... 80
see also cleanness, dirt, dust, clay.
Putnam County, glacial gravel in..... 207
mechanical analysis of gravel and sand from..... 206
Pennsylvanian sandstone in..... 181
Pyroxenses in sand, effect on color..... 8
Quarries, St. Peter sandstone, abandoned 151
St. Peter sandstone, Enterprise Sand and Mining Company..... 148
Glaser, J. W..... 160
Grays Summit White Sand Company.....157 159
illustrations, Franklin County..154, 160
illustrations, Jefferson County.....34, 42, 109, 145, 147
illustrations, St. Charles County.....155, 158, 160
illustrations, St. Louis County.....109, 145, 154, 155, 156
map of sand mine..... 148
Pacific Glass Sand Company..... 153
Pittsburg Plate Glass Company.144, 146
Silica White Sand Company..... 149
Tavern Rock Sand Company.....155-156, 159-160, 161-163
Quarrying sand, methods..... 39
Quarry run sand, see chemical analyses and mechanical analyses.
Quartz, definition of quartz sand..... 16
enlargement of, in sand..... 17
see also recrystallization.
in glacial gravels.....206, 207
in Missouri River sands..... 218
not altered by weathering..... 3
refractoriness of.....30, 74, 75
specific gravity of..... 18
usually carries the silica of sand.... 29
Quartzite, in glacial gravels.....203, 204, 205, 207
in Mississippi River sands..... 211
in Missouri River sand..... 218
Quartzitic sandstone, near faults.....135, 137, 138, 139
Commerce..... 191
Quartzose aggregate, usual conception of sand..... 1
Quaternary formations in table of formations..... 97
Quaternary sand and gravel, as a trade name..... 7
see also glacial gravels, and stream sands and gravels.
Quicksand, in pumping operations..... 36

Page
Railroad ballast, description of.....72, 73
see also ballast.
Railroad ties, concrete, construction of.. 63
Ralls County, cable drag line in..... 35
gravel bars in.....238-239
gravel plant in, illustrations.....34, 35
mechanical analysis of sand and gravel from..... 242
referred to..... 239
Randels, J. H., sand and gravel plant of. 231-232
sand and gravel plant of, illustration of..... 229
Rare-earths, present in monazite sands.. 6
Rattle Snake Creek, Devonian sandstone near..... 176
Ray County, asphaltic sandstone in.... 182
Recent sand and gravel.....211-244
as a trade name..... 7
Recomputing screen tests to 100 per cent 13
Recrystallization, in Gunter sandstone.. 92
in Roubidoux sandstone..... 94
in St. Peter sandstone..... 85
in quartz sand..... 17
see also quartz enlargement.
Recrystallized sand, used for stone-sawing..... 45
Red color, in Everton sandstone..... 104
in St. Peter sandstone, cause of...128-130
in sand, what due to.....8, 122-126
Red gravel, see Lafayette (?) gravel....
Red sands, rejection of..... 45
Refractoriness, in fire and furnace sand.. 85
in moulding sands.....74-75
in sands..... 30
Refractory brick, St. Peter used for.... 50
Regis Chauvenet & Company, analyses of St. Peter sandstone by....123-124, 169
Reinforced Concrete Committee of the National Association of Cement Users, cited on gravel specifications....57, 58
Renault quadrangle, as a base map for work..... XV
Renault sandstone, described..... 180
referred to.....88, 179
Reservoirs, concrete construction of.... 62
Residual deposits, description of..... 211
from Boone cherts..... 178
from Clear Creek (?) chert.....173-174
Residual gravel from granite..... 89
for road surfacing.....70, 71
Residual soil, at Jefferson City-St. Peter contact..... 111
origin of..... 3
Resistance of gravel to wear for road surfacing..... 59
Retardation of setting of cement due to clay.....11, 55
Reynolds, E. J., and Co., analysis of St. Peter sand from..... 125
Rhyolite of southeast Missouri, referred to..... 89
Richardson, Clifford, cited on asphalt paving material.....66, 67, 68
Richmond formation, in table of formation..... 88
Ries & Rosen, cited on foundry sands.73-77

Page
Rinker, R. P., analyses by..... XV
Riparian damages, referred to..... 48
Ripple marks, in Bolin Creek sandstone. 96
in Everton sandstone 103-104
in Gunter sandstone 92
in Roubidoux sandstone.....94, 97, 98
in St. Peter sandstone..... 118
River Aux Vases, escarpment along... 119
Everton sandstone near.....102, 103, 104
Everton sandstone near, illustration of..... 44
faulting near.....116, 138
mechanical analysis of Everton sandstone from..... 126
St. Peter sandstone near.106, 107, 139, 140
River gravels, see also Black River, Meramec, Osage, river sands, etc.
River sands and gravels, defined..... 5
described.....211-244
see also Mississippi, Missouri, Meramec, etc.
River wear, as an agent in forming sand. 2
Roach, A., gravel business of..... 241
Road metal, asphaltic sandstone for..181-189
described.....64-71
glacial gravel for.....204-208
granite residual for..... 89
Lafayette (?) gravel for.....190, 202-203
pits, illustrations of.....32, 174, 194
Rock Island Line, see Chicago, Rock Island & Pacific Railroad.
Rockport, glacial gravel near..... 207
Rolla, gravel from.....230, 238
mechanical analyses of sand and gravel from.....126, 242
Roubidoux sandstone near.....95-96
Rolla Quadrangle, Roubidoux described 93-96
Roofing gravel, description of..... 63
markets for..... 47
referred to in classification..... 8
screening plant for..... 43
size defined.....7, 227, 229
Rosen, See Ries and Rosen.
Rotary dryers for glass sand described.. .....44, 147, 156, 159, 163
Rotary screens, described..43, 231, 233-234
Roubidoux sandstone, analysis of, chemical.....123-124
analysis of, mechanical..... 126
described by counties.....93-100
for pavement cushion layer..... 66
for sand blast work..... 85
for stone-sawer's sand..... 85
recrystallization in..... 17
referred to.....89, 101, 108, 235
ripple marks referred to..... 118
sorting of..... 4
suitability for glass sand.....93-100
Roubidoux River, Roubidoux sandstone on..... 100
Roughness of grain, in concrete aggregates.....60-61
see also smoothness of grain.
Rounded grains, in Everton sandstone.. 104-105
in St. Peter sandstone.....127-128

Rounded Grains— Page
in sand, cause of 17
see also shape of grain, form of grain, sharpness, etc.
Rowley, R. R., cited on Vermicular sandstone 176
Royalties on sand and gravel 48, 232, 234
Rush Tower, escarpment near 119
glass sand near 152
Sabine, L. C., cited on clay in concrete .. 55
on cleanness of sand 10-11, 51
on coarseness desirable in mortar sand 16, 57
on form of grain desirable in sands 17-18, 60
on methods of washing sand 41
on organic matter in sands 56
on smoothness of gravel surfaces 61
on soundness of grain in sands 18
on strength of pebbles in concrete aggregate 61
Saccharoidal sandstone, same as St. Peter.
St. Charles City, see St. Charles County.
St. Charles County, glass sand plant in 34, 155, 161-163
glass sand plant, illustration of 155, 158, 160
gravel supply in 238
Missouri River sand from ..31, 219-220, 224
St. Peter sandstone, chemical analysis. 123-124
analysis, mechanical 126
description of 161-163
map of 161
referred to ....XIV, 49, 116, 157, 159, 161-163, 164
thickness of 112
St. Clair County, Pennsylvanian sand stone in 181
St. Clair, Stuart, cited on Cotter and Powell 101, 102, 103
on Everton sandstone 139
on Gunter sandstone 93
on Roubidoux sandstone 98
on St. Peter sandstone 112
mapping by XV
St. Elizabeth formation, same as Roubidoux 93-100
St. Francois County, Lamotte sandstone in 90
St. Francois Mountains, granite gravel from 69, 225, 231
St. Francois Mountains, granite in 89
Ste. Genevieve County, Aux Vases sandstone in 178 179
Chester sandstone, mechanical analysis of 126
escarpment in 119
Everton sandstone 102, 103, 105
illustration of 44
mechanical analysis of 126
faulting in 116, 142
Gunter sandstone in 93
Jefferson City-St. Peter contract in .. 110
Lamotte sandstone in 90
mechanical analysis of 126
Renault sandstone in 180

Page
Roubidoux sandstone described 98
St. Peter sandstone, description of ..138-141
map of 138
referred to 49, 106, 134, 164, 166
thickness of 112
Thebes sandstone in 172
Ste. Genevieve formation, referred to 88, 178, 179
St. James, market for Newburg sand 235
Roubidoux sandstone near 95
St. Joseph, as a sand shipping point 47
market for Osage River gravel 234
Missouri River sand from 219, 222, 223-224
sand plants at ...37, 38, 219, 222, 223, 224
illustrations of 39, 41, 223
sidewalk specifications referred to 63
St. Lorenz formation referred to 88, 175
St. Louis and Hannibal Railway glass sand along 169
gravel bars along 238 239
St. Louis and San Francisco Railroad, Aux Vases sandstone on 179
ballast pit of 34, 173 174
Commerce sandstone on 191
glass sand along 145, 149, 150, 151, 155
gravel plants on 227, 229, 230, 235, 236
Roubidoux deposits on 99
St. Peter sandstone along 138, 141
sand and gravel along 190, 213
St. Louis City, analysis of Mississippi River sand from 212
as a market for filter sand 214
as a market for gravel 191
as a market for Meramec gravel 59, 226, 227, 229, 230
as a market for St. Peter sand 50, 152
as a market for "silica" 174
distribution of sand from 46-47
glacial boundry near 203
Mississippi River sand from .213, 215-216
moulding sand pits in 308-209
illustrations of 208
office of Continental Portland Cement Company 226
of Grays Summit White Sand Company 157
of Meramec Portland Cement and Materials Company 215, 228
of Tavern Rock Sand Company .. 162
of Union Sand and Material Company 227, 228
of Universal Sand Company ...213, 229
sand plants at 38, 227-228
illustrations of 38, 39, 213, 215
sidewalk specifications referred to 63
St. Louis County, escarpment in 119
glass sand quarries in, illustrations of 109, 145, 154, 155, 156
gravel plants in 226-229
illustrations of 37, 40, 43
mechanical analysis of St. Peter sandstone 126
mechanical analysis of sand and gravel from 242
Mississippi River sand from 215-216

Page
St. Peter sandstone, analysis of....123-124
description of.....152-156
map of..... 152
mapping of.....XIV
referred to....49, 107, 131, 157, 159, 161
sand plants in illustrations of.....
.....38, 39, 154, 213, 215
see also St. Louis City.
St. Louis formation, referred to.....88, 178
St. Louis, Iron Mountain & Southern Railway, glass sand deposits along... 151
gravel bar, illustration of..... 236
gravel plants on.....232, 233
St. Peter sandstone along..... 133
St. Marys, mechanical analysis of Chester sandstone from..... 126
St. Peter sandstone near..... 134
St. Peter-Joachim escapment...104, 118-120
see also Joachim-St. Peter escarpment.
St. Peter sand, as a trade name..... 7
St. Peter sandstone, areal extent.....
....106-108, 131, 134, 138, 141, 152, 156, 161, 163, 165, 167
area of possible production..... 49
bedding in.....117-118
see also bedding.
Bollinger County, description of..... 134
Cape Girardeau County, description of.....131-134
cementation of.....39-40, 130
see also hardness, cementation, friability.
chemical analyses, tables of..122, 123, 125
color of.....128-130
composition of....121-126, 131, 133, 136, 137, 140, 144, 150, 151, 155, 158, 160, 162, 165, 166, 157, 168, 169
cross bedding in..... 118
degree of cementation of.....39-40, 130
see also cementation, friability, hardness.
degree of rounding of.....127-128
see also sharpness, shape of grain.
description of.....105-171
doubtful occurrence of.....170-171
escarpment of.....118-120
see also Joachim-St. Peter escarpment.
faulting in.....116-117
see also faults.
favorable localities for glass sand,....
.....132, 136, 139, 150, 156, 160, 163, 164, 166, 168
folding in.....115-116
see also folds, anticlines, and monoclines.
for fire and furnace sand..... 85
for moulding sand.....77, 210
for pavement cushion layer..... 66
for sand-blast work..... 85
for sand-lime brick..... 64
for stone-sawer's sand..... 85
Franklin County, description of..156-160
friability of.....39, 40
see also cementation, hardness.
Cape Girardeau County— Page
handled by hand..... 32
illustrations of, Cape Girardeau County..... 133
Franklin County.....159, 160
Jefferson County..34, 42, 109, 145, 147
Perry County..... 132
St. Charles County.....155, 158, 160
St. Louis County.109, 145, 154, 155, 156
impurities in..... 9
incorrectly called Roubidoux..... 93
Jefferson County, description of.....141-152
Lincoln County, description of.....167-170
lithologic character of....121-130, 131, 135, 139, 141, 152, 157, 161, 164, 166, 167
mapping of.....XIV, XV
map of, Callaway and Montgomery Counties..... 166
Cape Girardeau County..... 131
Jefferson County..... 141
Jefferson, Franklin and St. Louis Counties..... 152
Lincoln County..... 168
Perry County..... 134
Pittsburg Plate Glass Company's mine..... 148
Ste. Genevieve County..... 138
Warren and St. Charles Counties..... 161
mechanical analyses of, description..
.....126-128
methods of quarrying.....39-40
Montgomery County, description of..165-167
name of..... 105
only glass sand producer..... 84
Perry County, description of.....134-138
physiography of.....118-120
referred to....88, 92, 93, 95, 101, 102, 103, 104, 171, 175, 177, 180, 192
refractory character of..... 30
relation to Everton formation....111-112
relation to Jefferson City formation..
.....109 111
relation to Joachim formation....108-109
ripple marks in..... 118
St. Charles County, description of...161-163
Ste. Genevieve County, description of
..... 138-141
St. Louis County, description of....152-156
selection of grades..... 45
size of grains of.....126-127
stratigraphic relations of.....108-112
structure of.....115-118
thickness of....112-115, 132, 135, 139, 142, 153, 157, 161, 164, 166, 168
thorough sorting of..... 4
typical silica sand..... 6
uniformity coefficient of.....14-15
see also mechanical analyses.
uniformity of grain.....126-127
uses for, general.....64, 66, 77, 85, 210
uses for glass sand, see favorable localities, also glass sand.
Warren County, description of.....163-165
well rounded character of..... 17
whiteness of..... 53
Salem formation, referred to.....88, 178
Saline County, gravel supply in..... 241

Page
Saline Creek, escarpment along..... 119
St. Peter sandstone near..... 135
Salt River, gravel plant on.....35, 238-239
gravel plant on, illustrations of....34, 35
mechanical analyses of sand and gravel from..... 242
Sand, asphalt, see sand for asphalt pavements, and asphalt sand bedding, see sand for bedding, and bedding sand.
building, see sand for building and building sand.
classification of..... 5-8
cleanness, determination of.....9-11
concrete, see concrete, and sand for concrete.
Crushing Methods of..... 40
definition of..... 1
dredging, illustrations of.....
.....37, 213, 216, 220, 222, 223, 229
see also dredging, Mississippi River sands, Missouri River sands, Meramec, etc.
drying, methods of..... 43
illustration of..... 44
engine, see sand for engine, also engine sand.
filter, see filter sand and sand for filters.
for asphalt pavements, general discussion of.....66-69
for bedding stock cars, general discussion of..... 86
for bricklaying, general discussion of.....53-54
for building, general discussion of....51-64
for concrete, general discussion of...54-62
for engine sand, general discussion of.77-78
for filler in paper, referred to..... 86
for filters, general discussion of.....78-80
for fire sand, general discussion of.... 85
for foundry work, general discussion of.....73-77
for furnace lining, general discussion of..... 85
for glass making, general discussion of.....80-84
for grinding, general discussion of.... 84
for masonry, general discussion of.... 54
for minor uses, general discussion of.. 86
for mortar, general discussion of 51-54
for moulding casting, general discussion of.....73-77
for pavement cushion layers, general discussion of.....65-66
for pavement foundations, general discussion of..... 65
for paving, general discussion of....64-69
for plastering, general discussion of..51-53
for polishing, general discussion of ..84-86
for sand blast, general discussion of.. 85
for sanding painted surfaces, general discussion of..... 86
for sanding railroad tracks, general discussion of.....77-78
for sand lime brick, general discussion of..... 64
Sand— Page
for scouring soaps, referred to..... 86
for stone sawing, general discussion of.....84-85
for strikers on match boxes, referred to..... 86
foundry, see foundry sand, moulding sand, sand for moulding, etc.
furnace, see furnace sand, and sand for furnaces.
glass, see also glass sand, and sand for glass.
grinding, see grinding sand, and sand for grinding.
in railroad ballast..... 72
loading, see sand, method of loading.
markets.....46-50
methods of loading.....31-36
methods of production.....31-45
methods of unloading.....37-38
illustrations of....38, 39, 40, 41, 213, 215, 216, 220, 222, 223
mortar, see mortar sand, and sand for mortar.
moulding, see moulding sand, foundry sand and sand for moulding.
origin of..... 1-4
paving, see paving sand, asphalt sand, sand for paving, etc.
plastering, see plastering sand, and sand for plastering.
prices per ton, see prices, also costs.
producers, list of.....243-244
map showing location of..... 243
properties of.....8-30
chemical composition.....29-30
cleanness.....9-11
color..... 8
determined by screen tests.....11-14
effective size.....15-16
form of grain.....16-18
refractoriness..... 30
size of grain.....11-16
soundness of grain..... 18
specific gravity.....18-21
uniformity coefficient.....14-15
voids.....21-27
weight.....27-29
quarrying, methods of..... 39
illustrations of....34, 42, 109, 145, 147, 148, 154, 155, 156, 158, 159, 160
see also quarries, and St. Peter sandstone.
screening, methods..... 42
selection of grades.....35, 36, 44-45
size defined.....7, 227, 229
storage..... 44
unloading, see sand, methods of unloading.
uses of.....51 86
washing, methods of..... 10
see also gravel.
Sand and gravel, distribution of....87-224
occurrence of.....87-224
Sand blast, sand for..... 85
Sand dippers, use of..... 33
Sanding painted surfaces..... 86

Sanding rails, see engine sand. Page
Sand lime brick, sand for..... 64
Sandpaper, sand for..... 86
Sandstone, Aux Vases.....178-179
Beauvais.....174-175
Chester..... 126
Commerce.....191-193
Devonian.....74-176
distinguished from sand..... 1
Everton.....101-105
Gunter.....92-93
Lamotte.....89-91
Northview..... 177
Pennsylvanian.....180-189
Phelps..... 177
Renault..... 180
Roubidoux.....93-100
St. Peter.....105-171
Thebes..... 172
Vermicular..... 176
weathering of mechanically..... 2
see also St. Peter sandstone, Everton sandstone, etc.
Sassen, M., gravel plant of..... 234
Saturation, effect on weight of sand...28-29
Savage, T. E., cited on Clear Creek (?) chert..... 173
Savannah, market for Missouri River sand..... 224
Scarp, see escarpment.
Schists in Mississippi River sands..... 211
Schlicter, C. S., cited on effective size.. 15
on uniformity coefficient..... 14
on voids in sand..... 21
Schluersburg, St. Peter sandstone near.. 116
Scott County, Commerce sandstone in.. 191-192
gravel pits in, illustrations..... 194
Lafayette (?) gravel in..... 71
mechanical analyses of gravel and sand from.....126, 206
sand handled by hand..... 31
Tertiary gravel in.....71, 192, 193-200
Scouring soap, sand for..... 86
Scranton shale, in table of formations.. 87
Scraper and trap for loading sand..... 33
Screening, desirability for engine sand.. .....77-78, 235
desirability of, for grading purposes.. 59
for grinding sand..... 84
for railroad ballast.....72-73
for road gravel.....69-70
in glacial gravels..... 61
in Tertiary gravels.....198, 203
gravel, Arlington..... 236
Black River..... 231
Meramec River.....226-230
Osage River.....233-234
Screening sand, description of methods.42-43
glass sand plants..... .....147, 148, 154, 156, 159, 160, 163
Mississippi River..... 216
Screening tower, described..... .....40-41, 214, 226, 227, 231
illustrations of.....39, 40, 43, 229
Screen tests, by whom made..... XV
on minor streams, gravels of.....238-243
on Missouri River sands.....219-224
Screen tests— Page
on moulding sands.....75, 76
on Ozark gravels.....225-238
on St. Peter, table.....126, 127
on sands, general description of.....11-14
see also mechanical analyses.
Sea sands, defined..... 5
Season, length of, for dredging..... 39
Secondary quartz enlargement, see recrystallization, quartz enlargement.
Second Magnesian Limestone, same as Jefferson City.
Second sandstone, (Roubidoux).....93-100
Sedalia, gravel crushed at..... 40
analysis of sand at..... 121
gravel plant at..... 236
market for sand and gravel.....221, 236
sandstone near.....170, 171
Sedimentary rocks, weathering of mechanically.....2, 3-4
Segregation of weathered products.... 2-3
Selection, in weathering..... 2-4
of grades of sand, methods.....44-45
Selma, escarpment near..... 119
Selma Creek, escarpment along..... 119
Selma, Hollow, St. Peter sandstone along..... 150
Severy shade, in table of formation.... 87
Shale pebbles, in concrete aggregate.... 62
in filter sands and gravels..... 79
in Elk River gravel..... 242
Shales, weathering of.....2, 3, 4
Shape of grain, see also form of grain, sharpness, roundness.
Sharpness, cause and desirability in sands.....17-18
for asphalt pavements.....66, 67
for bricklaying sand..... 53
for concrete aggregates.....60-61
for engine sand.....77-78
for filter sands and gravels.....79, 80
for glass sand..... 81
for moulding sands..... 76
for pavement cushion layer.....65-66
for plastering sand..... 53
for railroad ballast..... 72
for road gravel..... 70
for sand-blast sand..... 85
for sand-lime brick..... 64
for stone masonry sand..... 54
for stone-sawer's sand.....84-85
of asphaltic sandstone.....186, 189
of Everton sandstone.....104-105
of Mississippi River sands..... 212
of Missouri River sands.....219-224
of Ozark gravels..... 225
of St. Peter sandstone.....127-128
over emphasis of..... 53
see also shape of grain, form of grain, and roundness.
Shawnee formation, in table of formations..... 87
Sheet asphalt, foundation for..... 65
Shelby County, gravel supply in.... .....207, 238, 239
Sheldon, asphaltic sandstone, near.... .....83, 184, 188-189
Shell, see clam shell.

Page
Shepard, E. M., cited on asphaltic sandstone ... 189
on Phelps sandstone ... 177
Sherman, as a shipping point for gravel. 47
gravel plant at ... 38, 40, 43, 215, 228-229
illustrations of ... 37, 43
Shifting of bars, effect on difficulty of dredging ... 35-36
Shipping points for sand ... 47
Shooting, in sand quarries ... 39
Shumard, B. F., cited on Devonian sandstone ... 176
on "Ferruginous Sandstone," ... 178, 189
on glacial gravel ... 207
on Roubidoux sandstone ... 98, 99, 100
on St. Peter sandstone ... 114, 132, 135, 139
on Thebes sandstone ... 172
on Vermicular sandstone ... 176, 177
Sidewalks, concrete construction of ... 63
Sieve tests on sands, general description of ... 11-14
Sikeston, market for Dexter gravel ... 243
Silex, analysis of St. Peter sandstone from ... 123-124
St. Peter sandstone near ... 117, 167, 168
Silica, cause of refractoriness in sands ... 74, 75, 76
content of, in fire and furnace sand ... 85
in St. Peter sandstone ... 121-126
in sand for glass ... 82
definition of silica sand ... 5-6
determined in analyses of sand ... 29
form in which present in sand ... 29
uses of sand for which a knowledge is essential ... 30
pit, tripolitic chert ... 173-174, 211
tripolitic chert, illustration of ... 174
see also chemical analyses.
Silica Station as a sand shipping point ... 47
glass sand quarry at ... 40
illustration of ... 42, 147
gravel plant at ... 36, 40, 233
illustration of ... 36
mechanical analyses of sand and gravel from ... 242
St. Peter escarpment near, illustration ... 109
St. Peter sandstone near ... 112, 143, 148, 151
Silicates as a flux ... 30
Silica White Sand Company's plant, description of ... 40, 142, 143, 148-150, 151
illustrations of ... 42, 147
Silicious sands, defined ... 5
Silos, concrete construction of ... 63
Silt, in Missouri River sands ... 218
in sand, discussed ... 9-11
see also dirt, and dust.
Silurian formation, in table of formations ... 88
Size, of glass sand deposits ... 83
Size of grain, as a basis of classification. 7
as a factor in defining sand ... 1
difficulty of selecting, in pumping operations ... 35-36
discussed ... 11-16
effective ... 14-15
Size of grain — Page
for asphalt pavements ... 66-67
for bricklaying sand ... 53
for concrete aggregate ... 54, 57, 58, 60
for engine sand ... 77-78
for filter sand and gravel ... 78-80
for glass sand ... 81, 82
for moulding sand ... 75
for pavement cushion layer ... 65-66
for plastering sand ... 51-52
for railroad ballast ... 72
for roofing gravel ... 63
for sandlime brick ... 64
for stone masonry sand ... 54
in Meramec gravel ... 226-229
in St. Peter sandstone ... 126, 127
screen tests to determine ... 11-14
uniformity coefficient ... 15-16
voids independent of ... 21
see also mechanical analyses, also Mississippi River sands, etc.
Size of screen mesh used for testing sand. 11
Skidmore, mechanical analyses of sand and gravel from ... 242
stream sand and gravel from ... 239-240
Slate pebbles, harmful in concrete aggregate ... 62
Slates, weathering of ... 2, 3, 4
Sligo market for Steelville sand ... 237
Slimes from washing St. Peter sand analysis ... 42
Smith, A. F., see Ball and Smith.
Smith, Geo. L., cited on age of glaciofluvial gravels ... 207
Smithville, glacial gravel near ... 207
Smoothness of grain, in concrete aggregate ... 60-61
of grain, in Everton sandstone ... 104-105
Snider, L. C., cited on Oklahoma asphalt sands ... 68, 185
Soda, presence of in sands ... 29-30
Soft grains, in sand for asphalt pavements ... 67
see also hardness.
Soil Survey maps, as base maps for work ... XIV, XV
Solubility of common rock-forming substances ... 3
Sorting of weathered products ... 2-3
Sounding for pumping operations ... 36
Soundness of grain desirable in sands ... 18
see also glacial gravels.
Sources of sand and gravel, production by ... 46
Southeast lowland, stream sands and gravels of ... 211
South Fork of Whitewater, St. Peter sandstone near ... 131
South Ottawa, Illinois, analysis of St. Peter sand from ... 125
South St. Louis, moulding sand from ... 77, 208-209
analysis of ... 209
Specifications, for filter sands and gravels ... 78-79
of sand, see also use of sand for special purposes required.

Page
Specific gravity, by whom determined.. XV
general discussion....18-21
of minor stream gravels....238-243
of Mississippi River sands....212-218
of Missouri River sands....219-224
of oil in asphalt sands.... 185
of Ozark gravels....225-238
of Tertiary sands and gravels....192-202, 206
range of in Missouri sands.... 21
relation to weight of sand.... 27
see also mechanical analyses.
Specific-gravity-weight, method of determining voids....25-26
Spergen formation, in table of formation.... 88
Springfield, asphaltic sandstone pavement tested in.... 189
market for sands....222, 235
Massachusetts, filter sand specifications of.... 79
Spring Fork Creek, gravel plant on.... 236
mechanical analyses of sand and gravel from.... 242
Spring River, Tertiary gravel along.... 189
Springs, from St. Peter sandstone.... 120
Sprott, Lamotte sandstone at.... 90
Stanton limestone in tables of formation. 88
Stark, C. N., gravel pit of.... 205
Statistics, table of comparative value of States' resources.... 45
table of prices of sand and gravel by years.... 48
of production of sand and gravel by sources.... 46
of production of sand and gravel by uses.... 45
Steam drills, use of.... 39
Steam shovel, illustration.... 34
used to load sand....34, 148, 163, 174
Steel casting, sand for....76- 85
Steelville, mechanical analyses of sand and gravel from.... 242
chemical analysis of sand from.... 237
sand handled by hand.... 32
sand shipped from.... 237
Stewart-Peck Sand Company's plant, description of....37, 222-223
illustrations of....40, 222
Steiger, George, anaslysis of St. Peter sand by....123-124
Stock piling sand....32. 37
illustrations of....39, 40, 41, 220, 222, 223
Stoddard County, gravel from.... 243
Lafayette (?) gravel in.... 71
mechanical analyses of gravel and sand from....206, 242
sand handled by hand in.... 31
Tertiary gravel in....71, 192, 200-201
Stone County, Tertiary gravel in.... 198
Stone masonry, sand suited for.... 54
Stone, R. W., cited on composition of moulding sands.... 76
on filter sands....78-79

Page
Stone-sawer's sand, properties of....84, 85, 155, 156
referred to in classification.... 8
selection of.... 45
Storage of sand.... 44
Straight, H. B., filter sand plant, description of....214-215
filter sand plant, illustration of.... 43
specifications for filter sand furnished by.... 80
Strange, C. W., gravel plant of....236-237
Stratification, effect of on voids....23-24
see also bedding.
Stratigraphic distribution as a basis for classifying sands.... 7
Stratigraphic relations of the St. Peter....108-112
Stratigraphy of sand formations....87-244
Stream gravels, not angular.... 70
Stream sands and gravels, discussion of....211-244
see also Mississippi, Meramec, etc.
Strength, essential element in masonry and concrete sands.... 53
of concrete effected by clay.... 10
of pebbles in concrete aggregate....61-62
Strikers on match boxes, sand for.... 86
Stripped structural plain, referred to.. 120
Stripping, see overburden.
Stromme, O. U., mapping by....XIV, 143
Structural gravel, Tertiary suited for.. 203
sand, described....52-64
sand, see also building sand, concrete sand and gravels, etc.
Structure of the St. Peter belt....115-118
see also folds, faults, etc.
Subways, concrete construction of.... 62
Sullivan pre-Combrian at.... 89
Sulphides, determined for what purposes.... 30
in concrete aggregate.... 57
Sulphur Springs, Devonian sandstone near.... 176
Sun cracks, in Bolin Creek sandstone.. 96
in Roubidoux sandstone.... 94
Surface of grain, in concrete aggregates....60-61
in sand for asphalt pavements.... 67
see also clay films.
Surfacing roads, gravel for....69-71
Swallow, G. C., cited on Gunter sandstone.... 92
on Tertiary quartzite.... 191
on Vermicular sandstone.... 176
Table of contents....III-IX
Tables, analysis of slimes from washing St. Peter sand.... 42
chemical analyses of St. Peter and Everton sandstone.... 122
of St. Peter from other states.... 125
of St. Peter sandstone previously published.... 123
see also chemical analyses.
Commercial sizes of sand and gravel... 60

Page

Comparison, of value of sand versus other resources 45
of washed and unwashed St. Peter sand .....
composition of natural rock asphalt from Oklahoma 68
cost data of washing ballast 73
desirable composition of moulding sand 76
Feret's sizes of sand 59
geological formations in Missouri ..87-89
mechanical analyses, asphaltic sandstone 176
glacial sands and gravels 206
Kaw River sands 224
Meramec River sands 242
minor streams gravels 242
Mississippi River sands 224
Missouri River sands 224
moulding sands from Herculaneum 210
moulding sands from St. Louis 209
Platte sands from St. Louis 209
Platte River sands 224
St. Peter sandstone 126
sandstone other than St. Peter 126
Tertiary sand and gravels 206
see also mechanical analyses.
method of computing uniformity coefficient 15
method of recomputing screen tests .. 13
prices of sand and gravel by years and uses 48
properties of concrete from Commerce gravels 195-197
production, of sand and gravel by sources 46
of sand and gravel by uses 45
sand sizes 7
screen meshes 12
screen tests, see also mechanical analyses.
size of filter bed gravel 79
Tanks, concrete construction of 62
Tarentum, Pennsylvania, glass plant at . 144
Tarkio limestone, in table of formation 87
Tavern Rock Sand Company, analysis of St. Peter sandstone from 123-124
mechanical analysis of St. Peter sandstone from 126
plant, description of .....
..34, 39, 40, 153, 155-156, 157, 159-160
illustrations of ..155, 156, 158, 159, 160
referred to 109, 129, 130
Taylor and Thompson, cited on clay in sands 52, 55
on definition of mortar 51
on definition of sand 1
on form of grain desirable in sands .18, 60
on graded sands, value of 53
on mica in concrete aggregate 62
on organic matter in sand ...11, 52, 54, 56
on properties desirable in concrete aggregate 54, 57
on relation between voids and uniformity coefficient 16
on size of grain for concrete work ..57, 58
on voids in sands 21, 22, 23, 58-59
on weight of sands 28

Page

Tecumseh limestone, in table of formations 87
Telephone poles, concrete, construction of 63
Temperature, as an agent in forming sand 2
Tennessee, Memphis, sand plant at ..215, 227
Tensile strength of Portland cement used in tests of Commerce gravel 195
Terra cotta, need of white sands for 8
Tertiary formation in table of formations 87
Tertiary sands and gravels, as a trade name 7
Commerce sandstone 191-192
Crowley's Ridge sands and gravels 192-203
described 189-203
excessive clay in 32, 55, 56
Lafayette (?) gravel, illustrations of 32, 174, 194
mechanical analyses of 242
Ozark region 189-191
percentage dirt in 10
referred to 127
Tests, necessary on sands 54
of concrete from Commerce gravel .. 195
on moulding sands 76
see also mechanical analyses, chemical analyses.
Texas, as a market for Missouri sands 47, 50, 59, 234
Texture, in moulding sands 75
see also size of grain and porosity.
Thebes sandstone, described 88, 172
Thickness, glass sand deposits 83
method of determining 113-114
of St. Peter sandstone ..112-115, 132, 135, 139, 142, 153, 157, 161, 164, 166 168
see also, formation in question.
Third sandstone, same as Gunter 92-93
Thompson pit, glacial gravel in 206
illustrations of 205, 207
mechanical analyses of gravel and sand from 206
Thompson, see Taylor and Thompson.
Thornhill, Will, gravel pit 205
Till, gravels 208
overburden, illustrations 204, 205, 207
overburden on Aftonian (?) 203, 204
Ton, as unit of sand marketing 46-47
price per, see price per ton.
Topeka limestone, in table of formations 87
Topography of the St. Peter formation 118-120
Torpedo gravels, for road surfacing 71
gravel, size defined 7, 227, 229
Toronto, Ontario, filter sand specifications of 79
Tourmaline in sand, effect on color 8
Tower Rock, Clear Creek (?) chert near 173
Track, for handling clam shell, described 37

Track— Page
for handling clam shell, illustrations.. .....38, 39, 40, 213, 216, 222
for unloading sand, described.....38, 41
Trade, names of sands..... 58
Tram, aerial, for handling sand....151, 183
for removing overburden, illustration..... 155
for unloading sand, illustration.... 41
see also track.
Transmittal, letter of.....XIII
Transportation, facilities, see details of individual deposits.
effect of on shape of grain..... 17
for glass sand deposits.....83, 84
Transportation, sorting by..... 2, 4
Trap, for handling sand, description of.....32, 33
see also loading trap..... 97
Trap Rock, crushed for filters..... 79
for road surfacing..... 69
in Black River gravels.....225. 231
in glacial gravels.....203, 204
in Mississippi River sands..... 211
Trenton formation, in table of formations..... 88
Tripoli, Clear Creek (?) chert.....173-174
Clear Creek (?) chert, illustration of.. 174
Trower, D. B., well on farm of..... .....115, 130, 167-168
Tuff, volcanic sand..... 5
Tunas, Gunter sandstone near..... 93
Tunnel methods of sand quarrying.. ..40, 145-147, 149, 151, 153, 159, 160, 173-174
methods of sand quarrying, illustrations.....42, 109, 145, 147, 155, 159
methods of sand quarrying, map.... 148
concrete construction of..... 62
Tuque Creek, St. Peter sandstone along.....164, 165
Turgite, possibly present in sands..... 29
Turner, H., Black River gravel and sand from..... 232
Tyler, W. S., and Company, screens manufactured by.....11-12
Ulrich, E. O., cited on relations of St. Peter and Joachim..... 109
Unconformity, at base of Aux Vases sandstone..... 179
at base of Everton sandstone..... .....101, 103, 111-112, 139, 143
at base of Lamotte sandstone..... 89
at base of St. Peter sandstone..... .....102, 109-111, 112
in Devonian.....174, 175
not probable, between Joachim and St. Peter..... 109
Underground method of sand mining, see tunnel methods.
Unequal heating, as an agent in forming sand..... 2
Unglaciated Mississippian area, gravel in.....211, 241-242
Unglaciated Pennsylvanian area, gravel in.....211, 241

Page
Uniformity coefficient, applied to concrete aggregate..... 58
by whom determined..... XV
curve of..... 15
general description of.....14-15
of filter sands and gravels.....78-80
of minor stream gravels.....238-243
of Mississippi River sands.....212-218
of Missouri River sands.....219-224
of Ozark gravels.....225-238
of St. Peter sandstone, table.....126, 12
of Tertiary sands and gravels..... .....192-202, 206
relation to voids.....21-23
see also mechanical analyses.
Uniformity of size of grain of the Everton sandstone..... 105
Union Sand and Materials Company's plants, description of.37, 215-217, 227-228
illustrations of.....38, 39, 215, 216
United States Silica Company, analysis of St. Peter sand from..... 125
Universal Sand Company's plants, decriptions of...36, 79, 213-214, 229-230
illustrations of.....213, 223, 229
Unloading sand, methods, illustrations of....38, 39, 40, 41, 213, 215, 216, 220, 222, 223
see also sand, methods of unloading.
Unwashed sand, see chemical analyses, St. Peter sandstone.
Upland gravels for road surfacing.....70, 71
uses of sand as a basis of classification. 8
table of production by..... 45
to which concrete is put.....62-63
see also St. Peter sandstone, Roubidoux sandstone glacial gravel, Tertiary gravel, etc.
Utica, Illinois, analysis of St. Peter sand from..... 125
Valda, gravel plant at..... 236
mechanical analyses of sand and gravel from..... 242
Valley Park, as a sand shipping point.. 47
glass plant of Pacific Glass Sand Company at.....153, 155
gravel plant at.....38, 40, 43, 226-227
illustration of..... 40
Value of sand and gravel, compared with other resources..... 45
by years..... 45
see also prices and cost.
Van Horn, F. B., and Buckley, E. R., cited in Devonian sandstone..... 175
Vegetable matter, see organic matter.
Veining in St. Peter sandstone, illustration..... 132
see also quartzitic sandstone.
Vermicular sandstone described....88, 176
referred to..... 177
Vernon County, asphaltic sandstone in...181, 182, 183, 184, 185, ..188-189
gravel supply in..... 241
Pennsylvanian sandstone in..... 181

Page
Versailles, analyses of sandstone from..123-124
Tertiary gravel at..... 190
Vilas shale in table of formations..... 88
Voids, by whom determined..... XV
considered in determining specific gravity.....19-20
general discussion of.....21-27
in concrete aggregate.....26, 58-60
in gravel for railroad ballast..... 72
in gravel for road surfacing.....69-70
in minor stream gravels.....238-243
in Mississippi River sands.....212-218
in Missouri River sands.....219-224
in sand for asphalt pavements.....66, 67
in Tertiary sands and gravels.192-202, 206
low percentage of, desirable in sand for plastering..... 52
range of, in Missouri sands..... 27
relation of to shape of grain....17-18, 60
relation to weight of sand..... 27
see also mechanical analyses.
Volatile matter, determined in analyses of sand..... 29
Volcanic ash, and sand, defined..... 5
Wabash Railroad, glass sand along.... 165
sand plants along..... 220
Wabaunsee formation in table of formations..... 87
Wagons, haulage of sand with.....31, 32
War Department, grants permission to dredge on navigable streams....47-48
Warsaw formation, referred to.....88, 178
Warren County, Devonian sandstone in..... 175
Jefferson City-St. Peter contact in... 110
Joachim-St. Peter contact in....108-109
St. Peter sandstone, descriptions..163-165
chemical analysis of.....122, 165
map of..... 161
mapping of.....XIV
mechanical analysis of..... 126
referred to.....49, 107, 116, 166
Warrensburg, referred to..... 187
Warrensburg sandstone, referred to.....181, 182, 183, 186
Washed sand, St. Peter sandstone, analyses..... 42
Washing, accompanying screening....43, 59
by centrifugal pumps.....36, 212-218
desirability of.....41-42
in glacial gravels.....56-61
on Tertiary gravels.....56, 198, 203
methods of.....40-42
of Arlington sand..... 236
of filter sands and gravels..... 79
of glass sand.....81, 83, 146-147, 154
of Meramec gravel.....226-230
of Mississippi River sand..... 216
of Missouri River sands..... 219
of Osage River gravel.....233-234
of railroad ballast.....72-73
plant of Straight, H. B..... 214
removes mud of green mud seams.... 128
result of on gravels, see gravel.
to determine silt (dirt).....9-11
Washing tower, see screening tower.
Washington County, Lamotte sandstone in..... 90
Washington, D. C., filter sand specifications of..... 78-7
Washington, Roubidoux sandstone near 98
Water, combined, present in sands....29-30
depth suitable for pumping operations..... 36
effect on weight of sands.....28-29
Waterproofing effect of clay in sand.....52, 55, 62
Wave attrition, as an agent in forming sand..... 2
Wayne County, Black River gravel and sand in.....232-233, 236
gravel plant referred to.....32, 33, 34
mechanical analysis of sand and gravel from..... 242
Weathering, in the formation of sand..2, 3-4
Weaver, H. H., abandoned quarry of.... 152
Webster County, Northview sandstone in..... 177
Vermicular sandstone on..... 176
Wedron, Illinois, analysis of St. Peter sand from..... 125
Wedron White Sand Company, analysis of St. Peter sand from..... 125
Weight, of minor stream gravels....238-243
of Mississippi River sands.....212-218
of Missouri River sands 219-224
of Ozark gravels.....225-238
of sand, general discussion.....27-29
range in Missouri sands..... 29
shipping weights of sand..... 47
of Tertiary sands and gravels.192-202, 206
per cubic foot and per cubic yard, see also mechanical analyses.
Weingarten quadrangle, as a base map for work..... XV
Weller, Stuart, cited on Aux Vases sandstone..... 178
cited on Beauvais sandstone..... 174
on Cap au Gres fault.....116-117
on Clear Creek (?) chert 173
on Devonian sandstone..... 176
on Renault sandstone..... 180
on St. Peter sandstone.....115,168
on Thebes sandstone..... 172
mapping by..... XV
Well, records, asphalt tests....186, 187 188
partial, giving thickness of St. Peter formation..113, 115, 129, 130, 132, 135, 142, 153, 157, 167-168
Weston shale, in table of formations... 88
West Point, Illinois, St. Peter sandstone near.....115, 168
Wetherholt gravel pit.....202, 206
Whetstone Creek, Roubidoux sandstone on..... 99
White color in sands, what due to.....8, 81
see also color.
White River, Tertiary gravel along.... 189
White Sand Company of Missouri, analysis of St. Peter sand from....123-124

Page
Whiteside, St. Peter sandstone near.117, 167
Whitewater River, Roubidoux sandstone on..... 100
St. Peter sandstone near..... 131
Whittenberg Creek, mechanical analysis of sand and gravel from..... 242
sand shipped from..... 237
Williams Hammer-Mill, referred to.....40, 148, 154
Williams, M. J., Tertiary gravel pits of..200-201, 206
Wilson, M. E., cited on asphaltic sandstone.....181-186
on Cap au Gres fault..... 117
on Clear Creek (?) chert..... 173
on Elk River gravel..... 242
on Grand Tower formation..... 174
on Phelps sandstone..... 177
on St. Peter sandstone..... 168
on Tertiary quartzite.....191-193
on Vermicular sandstone..... 176
Wind work as an agent in forming sand. 2
Winfield, Cap au Gres fault near..... 117
St. Peter sandstone near.....107, 168
Winslow, Arthur, cited on Gunter sandstone.....92, 93
on Roubidoux, Moreau and St. Peter. 93
on Roubidoux sandstone..... 89
on Tertiary..... 189

Page
Winterset limestone in table of formations..... 88
Witham, J. M., pit, glacial gravel in.... 207
Wittenburg, Aux Vases formations near. 178
Clear Creek (?) chert, described...173-174
illustration of..... 174
faulting near..... 116
St. Peter sandstone near..... 107
silica pit near.....34, 70, 73, 211
Wixford, J. F., analysis of St. Peter sand by.....123-124
Woody matter in sand, discussed..... 9-11
Worthington, glacial gravel near...206-207
Wright County, Northview sandstone in..... 177
Roubidoux sandstone described....98-99
Vermicular sandstone in..... 176
Wyoming, Cheyenne, market for filter sand..... 214

Yankeetown formation, in table of formations..... 88
Yard, as unit of sand marketing.....47-47
weight per, see also mechanical analysis.
Yellow color in sand, what due to..... 8
see also color.
Younger, see Mattox and Younger.
Zell, Everton sandstone near..... 102
St. Peter sandstone near..... 138